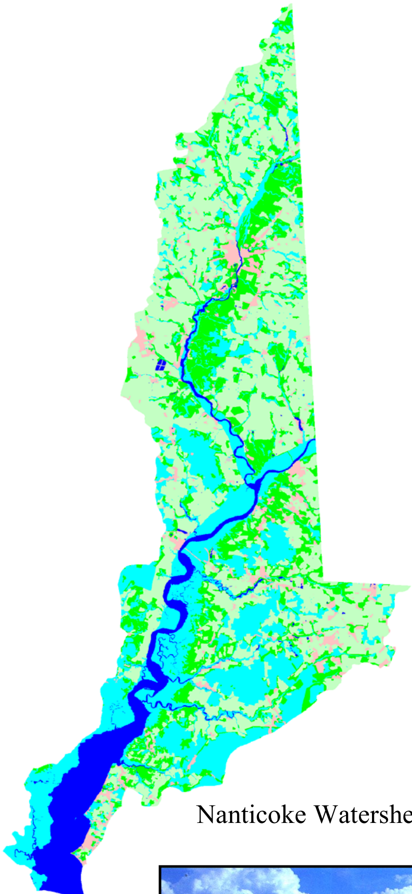
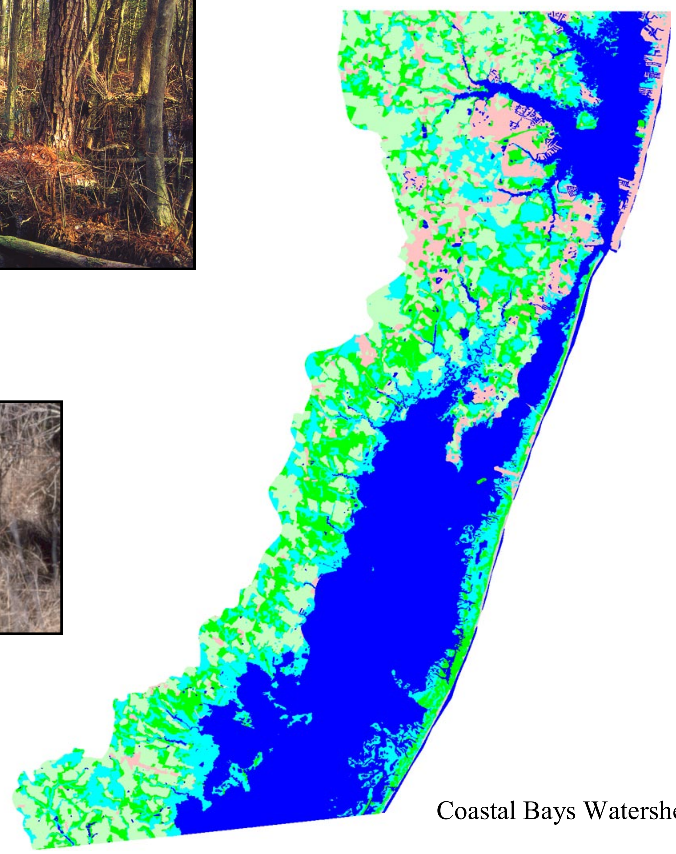
September 2000

Watershed-based Wetland Characterization for Maryland's Nanticoke River and Coastal Bays Watersheds:

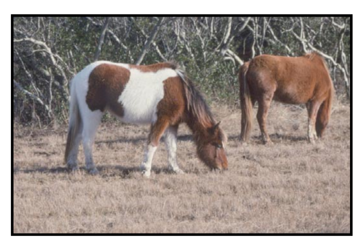
A Preliminary Assessment Report



Nanticoke Watershed



Coastal Bays Watershed



Watershed-based Wetland Characterization for Maryland's Nanticoke River and Coastal Bays Watersheds: A Preliminary Assessment Report

by

R. Tiner, M. Starr, H. Bergquist, and J. Swords

U.S. Fish and Wildlife Service
Northeast Region
National Wetlands Inventory Program
300 Westgate Center Drive
Hadley, MA 01035

Prepared for the Maryland Department of Natural Resources, Annapolis, MD[1]

September 2000

[1]This report is a publication for the Maryland Coastal Zone Management Program, Department of Natural Resources, pursuant to the National Oceanic and Atmospheric Administration Award No. NA87OZ0236.

This report should be cited as:

Tiner, R., M. Starr, H. Bergquist, and J. Swords. 2000. Watershed-based Wetland Characterization for Maryland's Nanticoke River and Coastal Bays Watersheds: A Preliminary Assessment Report. U.S. Fish & Wildlife Service, National Wetlands Inventory (NWI) Program, Northeast Region, Hadley, MA. Prepared for the Maryland Department of Natural Resources, Coastal Zone Management Program (pursuant to National Oceanic and Atmospheric Administration award). NWI technical report.

Table of Contents

Introduction

Today there is great interest in managing wetland resources from a watershed standpoint or landscape perspective. Wetland managers need information on a variety of topics including the location and type of existing wetlands, wetland functions, potential wetland restoration sites, and the overall condition of natural habitat in the watershed. The U.S. Fish and Wildlife Service's National Wetlands Inventory Program has developed products that expand the use of its conventional maps and digital products to aid in resource management. In particular, the NWI has improved and enhanced existing NWI databases to provide additional characteristics for mapped wetlands that are important for assessing potential wetland functions. The NWI has provided assistance to the State of Massachusetts in conducting watershed-wide inventories of potential wetland restoration sites. The NWI has also performed watershed-based analyses of the condition of natural habitat throughout watersheds while focusing on wetland and aquatic resources and their buffers. The State of Maryland is interested in using these sources of information for natural resource planning and provided funds to the Service to produce these products for two watersheds - the Nanticoke River watershed and the Coastal Bays watershed. This effort would be the first attempt at producing a watershed-based wetland characterization in the State. It could serve as a prototype of what might be done elsewhere in other watersheds. This work should help the State of Maryland develop a wetland protection strategy for individual watersheds that will address wetland acquisition, restoration, and other means of strengthening wetland protection in priority areas. It should serve as a foundation to build upon with additional site-specific studies.

Study Areas

The study areas are represented by two watersheds on Maryland's Eastern Shore on the Delmarva Peninsula -- the Nanticoke River watershed and the Coastal Bays watershed. The Nanticoke watershed covers an area approximately 323 square miles in size, encompassing parts of Dorchester, Wicomico, and Caroline Counties. Major tributaries of the Nanticoke River drainage basin are Marshyhope, Rewastico, Quantico, and Wetipquin Creeks. The watershed is comprised of 61 percent upland, 8 percent deepwater habitat, and 31 percent wetland. Estuarine waters total nearly 16,400 acres, while riverine tidal waters (610 acres) and lacustrine impoundments (330 acres) have a combined total of roughly 1000 acres. The Coastal Bays watershed occupies 296 square miles within Worcester County. The main waterbodies associated with the Coastal Bays watershed are Chincoteague, Newport, Sinepuxent, Isle of Wight, and Assawoman Bays, plus Greys Creek, and the St. Martin and Trappe Rivers. The watershed is comprised of 44 percent upland, 37 percent deepwater habitat, and 19 percent wetland. Nearly all (99%) of the deepwater habitats are estuarine (about 70,000 acres), with about 130 acres of lacustrine impoundments. General descriptions of wetlands associated with Maryland's Coastal Plain (which includes the study watersheds) can be found in "Wetlands of Maryland" (Tiner and Burke 1995) and are included as Appendix A of this report.

Methodology

The purpose of the project was to produce new information to assist Maryland wetland managers in wetland planning and evaluation at the watershed level. The foundation of this project was construction of a fairly comprehensive, geospatial wetland database. The existing wetland digital data for Maryland included the National Wetlands Inventory (NWI) data (based on 1:24,000 maps derived from mostly early 1980s-1:58K color infrared photography) and the State's wetland data (based on digital orthophoto quarter-quads produced from 1989-1:40K color infrared photographs). The NWI data were used as the foundation since they are part of a national database and match up well with other national digital data, especially hydrology data from the U.S. Geological Survey. The State data were used as collateral data to improve the delineation of wetlands in the NWI database.

The NWI database was also expanded to include hydrogeomorphic-type attributes for all mapped wetlands and waterbodies, an inventory of ditches, an inventory of potential wetland restoration sites, and geospatial data on land use and land cover in both watersheds. The information contained within the database was then used to produce summary statistics, thematic maps, and a wetland characterization report for the watersheds. The characterization included: 1) a summary of the extent and distribution of wetland types (by NWI type and hydrogeomorphic type), 2) a preliminary assessment of wetland functions for each watershed, 3) an inventory of potential wetland restoration sites, 4) a description of the condition of wetland and waterbody buffers, 5) an overall assessment of natural habitat for the watershed, and 6) an assessment of the extent of ditching. The following discussion addresses procedures used to produce this information. The report summarizes the study findings for each watershed. The results of this report should be considered preliminary as it has not been subject to agency or field review.

Improved Baseline NWI Data

While the project did not call for a comprehensive update of NWI maps, we needed a more complete and up-to-date wetland database for the characterization and analysis of wetland functions for each watershed. Consequently, the first task was to improve the existing wetland dataset since the pre-existing NWI data were both dated (derived from early 1980s photography) and conservative (e.g., many flatwoods were not mapped). Since a complete remapping of wetlands was not scheduled, we performed a rapid assessment revision of the wetlands data using a digital transfer scope to facilitate integration of existing digital wetland and hydric soil data with photointerpretation of spring 1998-1:40K black-and-white aerial photography. The digital data used to assist in updating were: 1) digital data for Maryland wetlands produced by the State from 1989 photography, 2) digital data on submerged aquatic vegetation (for the Coastal Bays) from the Virginia Institute of Marine Sciences (VIMS), and 3) hydric soil digital data from the U.S.D.A. Natural Resources Conservation Service's (NRCS) soil surveys. Using a digital transfer scope, the existing NWI database was updated and improved. Utilizing hydric soils digital data to help expand the mapping of flatwood wetlands may have led to some errors of commission (i.e., inclusion of upland forests in flatwood polygons). These wetlands tended to be classified as a seasonally saturated forested wetland of some kind (broad-leaved deciduous, needle-leaved evergreen, or mixed; NWI codes such as PFO1B, PFO4B, PFO1/4B, and PFO4/1B). In earlier NWI mapping, most of the mapped wet flatwoods were labelled as temporarily flooded, since ponding was observed in a few places. Since the 1980s, more inventory work has been done in the Coastal Plain and the hydrology of wet flatwoods has been determined to be best described as “seasonally saturated”. This is because high water tables are typical in winter and early spring, with little standing water present; locally they are called “winter wet woods”. The older classifications of these flatwoods were retained (e.g., PFO1A or PFO4A) for the most part due to time and budget considerations; these areas should be reclassified at some point in the future to produce a more consistent database. Nonetheless, this effort produced a more accurate database on the distribution, extent, and type of wetlands for the study watersheds. The VIMS data for submerged aquatic vegetation were simply imported and added to the wetland database for the Coastal Bays watershed. These data were derived from mapping based on 1998-1:24,000 black and white aerial photography. The NRCS data for hydric soils and Maryland state wetland data were mainly used as collateral sources to aid in flatwood wetland identification and the former also for assisting with wetland classification and predictions of wetland functions.

Expanded NWI Data

Once a more complete inventory of wetlands was created, the NWI database was further expanded by adding hydrogeomorphic-type information to each mapped wetland. Landscape position, landform, water flow path, and other descriptors were applied to all wetlands in the NWI digital database by merging NWI data with on-line U.S. Geological Survey topographic maps and consulting aerial photography where necessary (see Tiner 2000; Appendix B of this report for keys to these descriptors).

Landscape position defines the relationship between a wetland and an adjacent waterbody, if present. Five landscape positions are relevant to the study watersheds: 1) marine (along the ocean and open euhaline embayments), 2) estuarine (along sheltered euhaline bays and brackish embayments and rivers), 3) lotic (along freshwater rivers and streams), 4) lentic (in lakes, reservoirs, and their basins), and 5) terrene (isolated, headwater, or fragments of former isolated or headwater wetlands that are now connected to downslope wetlands via drainage ditches). Lotic wetlands are further separated by river and stream gradients as high (e.g., shallow mountain streams on steep slopes - not present in the study areas), middle (e.g., streams with moderate slopes - not present in the study areas), low (e.g., mainstem rivers with considerable floodplain development as in the Nanticoke watershed), and tidal (i.e., under the influence of the tides). "Rivers" are separated from "streams" solely on the basis of channel width: watercourses mapped as linear (one-line) features on an NWI map and a U.S. Geological Survey topographic map were designated as streams, whereas two-lined channels (polygonal features; two banks shown) on these maps were classified as rivers.

Landform is the physical form of a wetland or the predominant land mass on which it occurs (e.g., floodplain or interfluve). Six types are recognized in the study areas: basin, interfluve, flat, floodplain, fringe, and island (see Table 1 for definitions). Wetlands on the following soil types were considered to be floodplain wetlands: Chicone, Fluvaquents, Indiantown, Mannington, Mixed Alluvial Land, Nanticoke, Puckum, and Zekiah.

Additional modifiers were assigned to indicate water flow paths associated with wetlands:

throughflow, inflow, outflow, bidirectional, or isolated. Throughflow wetlands have either a watercourse or another type of wetland above and below it, so water flows through the subject wetland. Lotic wetlands are mostly throughflow types, except for lotic tidal ones (i.e., bidirectional flow or two-way flow). Inflow wetlands are sinks where no outlets exist, yet water is entering via a stream, river, or upslope wetland. Outflow wetlands have water leaving them and moving downstream via a watercourse or a slope wetland. Isolated wetlands are usually closed depressions or flats where water comes via surface water runoff or ground water discharge.

Other descriptors applied to mapped wetlands include headwater, drainage-divide, and fragmented. Headwater wetlands are sources of streams or wetlands along first order (perennial) streams. They include wetlands connected to first order streams by ditching; these wetlands were also labeled with a ditched modifier. Many such wetlands are remnants of once larger interfluve wetlands that drained directly into streams. Drainage-divide wetlands are wetlands that occur in more than one watershed, straddling the defined watershed boundary line between the subject watershed and a neighboring one. We also attempted to address the issue of fragmentation of wetlands. For this, wetlands separated by major highways (federal and state roads) and wetlands broken up by land development (e.g., farming) were considered fragmented wetlands. The latter type required examining the hydric soils data layer where available. In applying the fragmented descriptor, we attempted to cull out once larger wetlands that have been divided into smaller pieces. We did not apply the descriptor to wetlands that were simply reduced in size due to land use practices. The listing of fragmented wetlands is probably conservative.

For open water habitats such as the ocean, estuaries, lakes, and ponds, we also applied additional descriptors following Tiner (2000). For the study watersheds, such classification was mainly relevant for the estuaries and ponds.

Preliminary Assessment of Wetland Functions

After improving and enhancing the NWI digital database, several analyses were performed to produce a preliminary assessment of wetland functions for the watershed. Ten wetland functions were evaluated: 1) surface water detention, 2) streamflow maintenance, 3) nutrient transformation, 4) sediment and other particulate retention, 5) coastal storm surge detention and shoreline stabilization, 6) inland shoreline stabilization, 7) fish and shellfish habitat, 8) waterfowl and waterbird habitat, 9) other wildlife habitat, and 10) conservation of biodiversity. The rationale for correlating wetland characteristics with wetland functions is described in a later section of this report. After running the analyses, a series of maps for the watershed were generated to highlight wetland types that may perform these functions at high or other significant levels. Statistics and topical maps for the study area were generated by ArcView software.

Table 1. Definitions and examples of landform types (Tiner 2000).

Landform Type	**General Definition**	**Examples**
Basin*	a depressional (concave) landform	lakefill bogs; wetlands in the saddle between two hills; wetlands in closed or open depressions, including narrow stream valleys
Slope	a landform extending uphill (on a slope)	seepage wetlands on hillside; wetlands along drainageways or mountain streams on slopes
Flat*	a relatively level landform, often on broad level landscapes	wetlands on flat areas with high seasonal ground-water levels; wetlands on terraces along rivers/streams; wetlands on hillside benches; wetlands at toes of slopes
Floodplain	a broad, generally flat landform occurring on a landscape shaped by fluvial or riverine processes	wetlands on alluvium; bottomland swamps
Interfluve	a broad level to imperceptibly depressional poorly drained landform occurring between two drainage systems (on interstream divides)	flatwood wetlands on coastal or glaciolacustrine plains
Fringe	a landform occurring along a flowing or standing waterbody (lake, river, stream) and typically subject to permanent, semipermanent flooding or frequent tidal flooding; including wetlands within stream or river channels and estuarine wetlands with unrestricted tidal flow	buttonbush swamps; aquatic beds; nonpersistent emergent wetlands; salt and brackish marshes
Island	a landform completely surrounded by water (including deltas)	deltaic and insular wetlands; floating bog islands

*May be applied as sub-landforms within the Interfluve and Floodplain landforms.

Wetland Restoration Site Inventory

Wetland restoration efforts have been accelerating over the past decade. Much of the work done to date has been on an ad-hoc basis without knowledge of a broader universe of potential sites. In most areas of the country, site selection for wetland restoration has simply been driven by opportunities and not by a holistic view of watersheds and wetland resources. Recently, the State of Massachusetts initiated a watershed-based restoration process, where potential wetland restoration sites are identified throughout an entire watershed, then matched with locations of various "watershed-deficits" (e.g., flooding problems, areas of degraded water quality, and areas lacking connectivity between significant fish and wildlife habitats) in an effort to promote wetland restoration where the greatest public good can be gained. Such work provides agencies, organizations, and others interested in wetland restoration with a wide selection of potential sites. The Maryland Department of Natural Resources is interested in this process, so we also identified potential wetland restoration sites for the two watersheds.

An inventory of potential wetland restoration sites was performed by examining aerial photos, hydric soil information, and existing wetland data (e.g., for farmed wetlands, wetlands experiencing possible hydrologic restrictions, plus diked, ditched, and excavated vegetated wetlands). Two major types of wetland restoration sites were identified: Type 1 sites - former vegetated wetlands that appear suitable for restoration, and Type 2 sites - existing vegetated wetlands whose functions appear to be significantly impaired by ditching, excavation, and impoundment. Type 1 restoration sites included former wetlands that were filled and that did not have buildings or other facilities constructed on them, farmed wetlands, and vegetated wetlands that were converted to deepwater habitats such as impounded lakes. Farmed wetlands may technically be considered Type 2 candidates, but since their condition is impaired to the point that they only minimally meet the definition of wetland in the subject areas, they were considered Type 1 sites. Type 2 restoration sites are mostly existing vegetated wetlands that are impounded, excavated, partly drained (ditched), and potentially tidally restricted, but also include shallow ponds which are technically considered wetlands by the Cowardin et al. (1979) wetland classification system. The latter sites may arguably be considered Type 1 sites for restoration, but for this study were identified as Type 2 sites. For ditched wetlands, no attempt was made to evaluate the severity of ditching as this requires field-based assessments. One, however, might consider the degree of ditching as observed on the map showing the extent of ditching as a way of evaluating the relative impact of ditching on various wetlands. Type 2 sites could be expanded to include wetlands where the adjacent land use may have significant effects on the quality of the wetland, but this was not an objective of this project. Many, if not most, wetlands in the subject watersheds could be highlighted as having potentially significantly adverse impacts from adjacent land use practices as many wetlands are surrounded by cropland. Many of these wetlands, however, were identified as being adversely impacted by ditching.

Sites identified as potential wetland restoration sites appeared to be restorable to vegetated wetlands in some way. Sites such as ponds on hydric soils and now surrounded by residential development were not considered to be viable sites. However, ponds and farmed wetlands surrounded by cropland (within hydric soil map units) were considered to have some restoration potential. Theoretically such sites could be restored to large forested wetlands with landowner permission due to the presence of extensive drained hydric soils in the surrounding agricultural fields.

Wetland and Waterbody Buffer Analysis

A 100m-wide buffer has been reported to be important for neotropical migrant bird species in the Mid-Atlantic region (Keller et al. 1993) and streamside vegetation providing canopy coverage over streams is important for lowering stream temperatures and moderating daily fluctuations that is vital to providing suitable habitat for certain fish species (e.g., trout). Review of the literature on buffers suggests wider buffers, such as 500m or more for certain species of wildlife (e.g., Kilgo et al. 1998 for southern bottomland hardwood stream corridors). An interesting article by Finlay and Houlahan (1996) indicates that land use practices around wetlands may be as important to wildlife as the size of the wetland itself. They reported that removing 20 percent of the forest within 1000m of a wetland may have the same effect on species as destroying 50 percent of the wetland. For literature reviews of wetland and stream buffers, see Castelle et al. (1994) and Desbonnet et al. (1994).

The condition of these buffers is also significant for locating possible sources of water quality degradation. Wooded corridors should provide the best protection of water quality, while developed corridors (e.g., urban or agriculture) should contribute to substantial water quality and aquatic habitat deterioration. Since wetland and waterbody buffers are important features that relate to the quality of these aquatic habitats, we performed an analysis of the condition of these buffers. This information was also used for evaluating the overall ecological condition or the condition of natural habitats for each watershed.

A 100m-wide buffer was selected for analysis. The buffer was positioned around wetlands, waterbodies, and ditches. To evaluate the condition of the upland buffer, we created a land use/land cover data layer by combining existing digital data with new photointerpretation. The state's existing digital data on land use/land cover was used as the baseline data. These data were updated by interpreting 1998 aerial photography (1:40,000 black and white) using a digital transfer scope. We used the Anderson et al. (1976) land use/land cover classification system and classified upland habitats to level two in the system. The following categories were among those identified: developed land (residential, commercial, industrial, transportation/communication, utilities, other, institutional/government, and recreational, farmsteads/farm-related buildings), agricultural land (cropland/pasture, orchards/nurseries/horticulture, and feedlots/holding areas), forests (deciduous, evergreen, mixed, and clear-cut), wetlands (from NWI data), and transitional land (moving toward some type of development or agricultural use, but future status unknown). Data layers were constructed for the entire "land" area of each watershed so that information could also be used for assessing their overall ecological condition. Buffer analysis is one of the key landscape variables used to judge this condition.

Overall Ecological Condition of the Watershed

There are many ways to assess land use/cover changes and habitat disturbances. The health and ecological condition of a watershed may be assessed by considering such features as the integrity of the lotic wetlands and riparian forests (upland forests along streams), the percent of land uses that may adversely affect water quality in the watershed (% urban, % agriculture, % mining, etc.), the actual water quality, the percent of forest in the watershed, and the number of dams on streams, for example. Recent work on assessing the condition of watersheds has been done in the Pacific Northwest to address concerns for salmon (Wissmar et al. 1994; Naiman et al. 1992). A Wisconsin study by Wang et al. (1997) found that in-stream habitat quality declined when agricultural land use in a watershed exceeded 50 percent, while when only 10-20 percent of the watershed was urbanized, severe degradation occurred.

To assess the overall ecological condition of watersheds, the Northeast Region of the U.S. Fish and Wildlife Service has developed a set of largely remotely-sensed “natural habitat integrity” indices. The variables for these indices are derived through air photointerpretation and/or satellite image processing coupled with knowledge of the historical extent of wetlands and open waterbodies. They are coarse-filter variables for assessing the overall condition of watersheds. They are intended to augment, not supplant, other more rigorous, fine-filter approaches for describing the ecological condition of watersheds (e.g., indices of biological integrity for macroinvertebrates and fish and the extent and distribution of invasive species) and for examining relationships between human impacts and the natural world. The natural habitat integrity indices can be used to develop “habitat condition profiles” for individual watersheds of varying scales (i.e., subbasins to major watersheds). Indices can be used for comparative analysis of subbasins within watersheds and to compare one watershed with another. They may also serve as one set of statistics for reporting on the State-of-the-Environment by government agencies and environmental organizations.

The indices are rapid-assessment types that allow for frequent updating (e.g., every 5-10 years). They may be used to assess and monitor the amount of “natural habitat” compared to the amount of disturbed aquatic habitat (e.g., channelized streams, partly drained wetlands, and impounded wetlands) or developed habitat (e.g., cropland, grazed meadows, mined lands, suburban development, and urbanized land). The index variables include features important to natural resource managers attempting to lessen the impact of human development on the environment. The indices may also be compared with other environmental quality metrics such as indices of biological integrity for fish and/or macroinvertebrates or water quality parameters. If significant correlations can be found, they may aid in projecting a “carrying capacity” or threshold for development for individual subbasins. This would require further classification of the developed land category into agricultural types and urban/suburban types which is easily accomplished.

To date, a total of 9 indices have been developed. All of them, in one way or another, represent habitat condition in a watershed. Five indices address natural habitat extent (i.e., the amount of natural habitat occurring in the watershed and along wetlands and waterbodies): natural cover, stream corridor integrity, wetland and other waterbody buffer integrity, wetland extent, and standing waterbody extent. Use of terms like “natural habitat” and “natural vegetation” have stirred much debate, yet despite this, we feel that they are useful for discussing the effects of human activities on the environment. For purposes of this study, “natural habitats” are defined as areas where significant, frequent human activity is limited to nature observation, hunting, and fishing, and where vegetation is allowed to grow for many years without annual introduction of chemicals or annual harvesting of vegetation or fruits and berries for commercial purposes. Natural habitats may be managed, but they are places where wetland and terrestrial wildlife find food, shelter, and water. In other words, they are essentially plant communities represented by "natural" vegetation (such as forests, meadows, and shrub thickets). They are not developed sites (e.g., not impervious surfaces, lawns, turf, cropland, heavily grazed pastures, or mowed hayfields). Managed forests are included as natural habitat, whereas orchards and vineyards are not. "Natural habitat" therefore includes habitats ranging from pristine woodlands and wetlands to wetlands now colonized by invasive species (e.g., Phragmites australis or Lythrum salicaria) or commercial forests planted with loblolly pine. Natural vegetation does not imply that substantial groundcover must be present, but simply that the communities reflect the vegetation that is capable of growth and reproduction in accordance with site characteristics. Consequently, areas with sparse vegetation, such as sand dunes and beaches, qualify as natural habitat.

Three indices emphasize human-induced alterations to streams and wetlands. These "stream and wetland disturbance indices" address dammed stream flowage, channelized stream flowage, and wetland disturbance. The 8 specific indices may be combined into a single, composite index called "remotely-sensed natural habitat integrity index" for the watershed. All indices have a maximum value of 1.0 and a minimum value of zero. For the habitat extent indices, the higher the value, the more habitat available. For the disturbance indices, the higher the value, the more disturbance. For the remotely-sensed natural habitat integrity index, all indices are weighted, with the disturbance indices subtracted from the habitat extent indices to yield an overall "natural habitat integrity" score for the watershed.

Data for these indices came from the improved NWI digital database and a newly created land use/land cover database for the two watersheds. The data were derived primarily through aerial photointerpretation with review of existing information. Presently, the indices do not include certain qualitative information on the condition of the existing habitats (habitat quality) as reflected by the presence, absence, or abundance of invasive species or by fragmentation of forests, for example. It may be possible to add such data in the future, especially for the latter. Another consideration would be possible establishment of minimum size thresholds to determine what constitutes a viable "natural habitat" for analysis (e.g., 0.04 hectare/0.1 acre patch of forest or 0.4 hectare/1 acre minimum?). Other indices may also need to be developed to aid in water quality assessments (e.g., index of ditching density for agricultural and silvicultural lands). The 9 indices are summarized below.

Habitat Extent Indices

The Natural Cover Index (I_{NC}) is derived from a simple percentage of the subbasin that is wooded (e.g., upland forests or shrub thickets and forested or scrub-shrub wetlands) or "natural" open land (e.g., emergent wetlands or open, "old" fields; but not cropland, hayfields, lawns, turf, or heavily grazed pastures) - lands supporting "natural vegetation" (excluding open water of ponds, rivers, lakes, streams, and coastal bays):

$$I_{NC} = A_{NV}/A_W$$

where A_{NV} (area in natural vegetation) equals the area of the watershed's land surface in "natural" vegetation (e.g., woodland, open land [wildlife habitat, not farms, golf courses, ballparks, or playgrounds], and vegetated wetland). This index addresses only the "land" portion of the watershed (excludes open water from the calculations), so the area of "watershed" (A_W) for this index disregards the area occupied by open water.

The <u>Stream Corridor Integrity Index</u> (I_{SCI}) is derived by considering the condition of the stream corridors:

$$I_{SCI} = A_{VC}/A_{TC}$$

where A_{VC} (vegetated stream corridor area) is the area of the stream corridor that is colonized by "natural vegetation" and A_{TC} (total stream corridor area) is the total area of the stream corridor. The width of the stream corridor may be varied to suit project goals, but for this index, a 100-meter corridor (50m on each side of the stream) will usually be evaluated (at a minimum), due to its well-recognized role in water quality maintenance and contributions to aquatic habitat quality. If wildlife travel corridors are a primary concern, a larger corridor (e.g., 200m to 1000m) may be examined. The stream corridor may be restricted to "streams" (linear tributaries on a 1:24,000 map) or expanded to include "rivers" (polygonal features at this scale). If the latter is included in the index, it should be referred to as the River/Stream Corridor Integrity Index (I_{RSCI}).

The <u>Wetland and Other Waterbody Buffer Index</u> (I_{WWB}) is a measure of the condition of wetland and waterbody buffers within a specified distance (e.g., 100m) of mapped wetlands and waterbodies (mainly lakes and estuaries, excluding river/stream or stream corridors) for the entire watershed:

$$I_{WWB} = A_{VB}/A_{TB}$$

where A_{VB} (area of vegetated buffer) is the area of the buffer zone that is in natural vegetation cover and A_{TB} is the total area of the buffer zone. The buffer zone can include or exclude open water, with the latter emphasizing land use and land cover changes.

The <u>Wetland Extent Index</u> (I_{WE}) addresses the current extent of vegetated wetlands (excluding open-water wetlands) compared with the estimated historic extent - the approximate percent of wetlands remaining in the watershed:

$$I_{WE} = A_{CW}/A_{HW}$$

where A_{CW} is the current wetland area in the watershed and A_{HW} is the historic wetland area in the watershed (estimated).

For example, a watershed with a coverage of 10 percent wetland would have an I_{WE} of 1.0 where the estimated original extent of wetlands was 10 percent or an I_{WE} of 0.5 where 20 percent of the watershed once contained wetlands. The I_{WE} is an approximation of the extent of the original wetland acreage remaining in the watershed. If data on historical wetland area are not available, calculate this by either evaluating a relatively undisturbed subwatershed in the watershed (i.e., one with similar properties of landscape, soils, and surficial geology) or using the area of hydric soils (including land types that are predominantly wetlands such as swamp or tidal marsh) as the historic extent of vegetated wetlands. Recognize that areal extent of historic hydric soils could be less than the current extent due to level of mapping detail (e.g., scalar issues) or to wetland-creation activities, especially due to beaver influence and shallow pond construction. When the current extent of wetlands (e.g., percent of watershed) is greater than the historic estimate, for purposes of this landscape-level assessment, it is assumed that wetland change has not been significant and the I_{WE} is recorded as 1.0.

The Standing Waterbody Extent Index (I_{SWE}) considers the current extent of standing fresh waterbodies (e.g., lakes, reservoirs, and open-water wetlands - ponds) in a watershed relative to the historic area of such features:

$$I_{SWE} = A_{CSW}/A_{HSW}$$

where A_{CSW} is the current standing waterbody area and A_{HSW} is the historic standing waterbody area in the watershed.

The historic number is created by either consulting older USGS topographic maps or simply by subtracting the area of new large fresh waterbodies (e.g., reservoirs and large impoundments) from the current area. When it is obvious that extensive open waterbodies have been created (i.e., reservoirs, impoundments, ponds, and excavations) and the total area of open water has increased, it is not necessary to calculate this index. Simply, use a I_{SWE} value of 1.0 when applying this index to determine the remotely-sensed natural habitat integrity index. This is the case for many watersheds, especially those in agricultural and urban/suburban areas.

Stream and Wetland Disturbance Indices

The Dammed Stream Flowage Index (I_{DSF}) is a measure that attempts to highlight the direct impact of damming on rivers and streams in a watershed:

$$I_{DSF} = L_{DS}/L_{TS}$$

where L_{DS} is the length of perennial rivers and streams impounded by dams (combined pool length) and L_{TS} is the total length of perennial rivers and streams in the watershed. It does not attempt to predict the magnitude of downstream effects from such dams as they are not readily predicted from aerial photointerpretation or geographic information system technology.

The Channelized Stream Length Index (I_{CSL}) addresses the extent of channelization of streams within a watershed relative to its total stream length:

$$I_{CSL} = L_{CS}/L_{TS}$$

where L_{CS} is the channelized stream length and L_{TS} is the total stream length for the watershed. This index only addresses stream channelization; it does not include the length of artificial ditches excavated in farmfields and forests. It will usually emphasize perennial streams, but could include intermittent streams, if desirable.

The Wetland Disturbance Index (I_{WD}) is a measure of the extent of existing wetlands that are diked/impounded, ditched, or excavated:

$$I_{WD} = A_{DW}/A_{TW}$$

where A_{DW} is the area of disturbed or altered wetlands and A_{TW} is the total wetland area in the watershed. Wetlands are represented by vegetated and nonvegetated (e.g., shallow ponds) types and include natural and created wetlands.

Composite Habitat Index for the Watershed

The Index of Remotely-sensed Natural Habitat Integrity (I_{RNHI}) is a combination of the preceding indices. It seeks to express the overall condition of a watershed in terms of its potential ecological integrity or the relative intactness of natural plant communities and waterbodies. Variations of I_{RNHI} may be derived by considering buffer zones of different widths around wetlands and streams (e.g., $I_{RNHI\ 100}$ or $I_{RNHI\ 200}$) and by applying different weights to individual indices. An example is given below emphasizing a 100-meter buffer:

$$I_{RNHI\ 100} = (0.6 \text{ x } I_{NC}) + (0.1 \text{ x } I_{SCI200}) + (0.1 \text{ x } I_{WWB100}) + (0.1 \text{ x } I_{WE}), + (0.1 \text{ x } I_{SWE}) - (0.1 \text{ x } I_{DSF}) - (0.1 \text{ x } I_{CSL}) - (0.1 \text{ x } I_{WD})$$

where the condition of the 100m buffer is used throughout. (Note: With this size buffer, the stream corridor width becomes 200m.)

Ditch Inventory

To determine the extent of ditches in each watershed, we began with the digital hydrology coverage from the U.S. Geological Survey 1:24K map series (digital line graphs - DLGs). This coverage was reviewed through photointerpretation to help separate “natural streams” from “ditches” and formed the foundation for the “ditch” data layer. To create an up-to-date “ditch” coverage, photointerpretation of 1998 aerial photography[1] was performed using a digital transfer scope. Ditches were separated from channelized and natural streams. Data presented include number of ditch miles and the density of ditches per study watershed.

[1]For the Nanticoke watershed, initial mapping of ditches was accomplished by photointerpreting 1989 photos since the 1998 photos were not available until later in the project. These data were updated with the 1998 photos to create a 1998-era database for ditches.

General Scope and Limitations of the Study

Wetland Inventory and Digital Database

The wetlands inventory and digital database do not represent a complete re-inventory of wetlands in the subject watershed. They are, however, a significant improvement and update of the original NWI database and can serve as a foundation for a preliminary watershed characterization. Mapping of flatwood wetlands may be liberal due to the use of hydric soil data to aid in their interpretation.[1] One must recognize the limitations of any wetland mapping effort derived mainly through photointerpretation techniques (see Tiner 1997 for details). For example, use of spring aerial photography for wetland mapping precludes identification of freshwater aquatic beds. Such areas are included within areas mapped as open water (e.g, lacustrine and palustrine unconsolidated bottom) because vegetation is not developed so they appear as water on the aerial photographs. Also drier-end wetlands such as seasonally saturated and temporarily flooded wetllands are often difficult to separate from nonwetlands through photointerpretation. Future ground-truthing exercises will need to be performed to further improve the database.

An attempt was made to apply a "fragmented" descriptor to highlight wetlands that are fragments of once-larger wetlands. In the study watersheds, many wetlands are separated into variously-sized parcels due to agricultural land uses. Obvious fragments were identified. For some small wetland areas, it was not possible to readily determine whether they were fragments of a once larger interfluve wetland without reviewing of soil information and land use/cover data to verify the occurrence of a once larger wetland. This was done where digital soils data were available (e.g., entire Coastal Bays watershed and the Dorchester County portion of the Nanticoke watershed). The use of the fragmented descriptor should be considered conservative. Future discussion of what situation constitutes sufficient fragmentation to be highlighted for natural resource planning purposes may improve future application of this descriptor.

Preliminary Assessment of Wetland Functions

At the outset, it is important to emphasize that this functional assessment is a preliminary one based on wetland characteristics interpreted through remote sensing and using the best professional judgment of the authors, two U.S. Fish and Wildlife Service field offices (Chesapeake Bay Field Office and Delaware Bay Estuary Project Office), and staff from the Maryland Department of Natural Resources. Wetlands believed to be providing potentially high or other significant levels of performance for a particular function were highlighted. As the focus of this report is on wetlands, an assessment of deepwater habitats (e.g., lakes, rivers, and estuaries) for providing the listed functions was not done (e.g., it is rather obvious that such areas provide significant functions like fish habitat). Also, no attempt was made to produce a more qualitative ranking for each function or for each wetland based on multiple functions as this would require more input from others and more data, well beyond the scope of this study. For a technical review of wetland functions, see Mitsch and Gosselink (2000) and for a broad

[1]Differences in projections and base map source data caused a mismatch between state wetland digital data and federal digital data (e.g., U.S. Geological Survey digital line graphics) which unfortunately precluded broad use of the former. Time was not available to rectify this problem.

overview, see Tiner (1998).

Functional assessment of wetlands can involve many parameters. Typically such assessments have been done in the field on a case-by-case basis, considering observed features relative to those required to perform certain functions or by actual measurement of performance. The present study does not seek to replace the need for such evaluations as they are the ultimate assessment of the functions for individual wetlands. Yet, for a watershed analysis, basinwide field-based assessments are not practical or cost-effective or even possible given access limitations. For watershed planning purposes, a more generalized assessment is worthwhile for targeting wetlands that may provide certain functions, especially for those functions dependent on landscape position and vegetation life form. Subsequently, these results can be field-verified when it comes to actually evaluating particular wetlands for acquisition purposes, e.g., for conservation of biodiversity or for preserving its flood storage function. Current aerial photography may also be examined to aid in further evaluations (e.g., condition of wetland/stream buffers or adjacent land use) that can supplement our preliminary assessment.

This study employs a watershed assessment approach that may be called "Watershed-based Preliminary Assessment of Wetland Functions" (W-PAWF). W-PAWF applies general knowledge about wetlands and their functions to develop a watershed overview that highlights possible wetlands of significance in terms of performance of various functions. To accomplish this objective, the relationships between wetlands and various functions must be simplified into a set of practical criteria or observable characteristics. Such assessments could also be further expanded to consider the condition of the associated waterbody and the neighboring upland or to evaluate the opportunity a wetland has to perform a particular function or service to society, for example.

W-PAWF usually does not account for the opportunity that a wetland has to provide a function resulting from a certain land use practice upstream or the presence of certain structures or land uses downstream. For example, two wetlands of equal size and like vegetation may be in the right landscape position to retain sediments. One, however, may be downstream of a land-clearing operation that has generated considerable suspended sediments in the water column, while the other is downstream from an undisturbed forest. The former should be actively performing sediment trapping in a major way, while the latter is not. Yet if land use conditions in the latter subwatershed area change, the second wetland will likely trap sediments as well as the first wetland. The entire analysis typically tends to ignore opportunity since such opportunity may occurred in the past or may occur in the future and the wetland is awaiting a call to perform this service at higher levels than presently. An exception would be for a wetland type that would not normally be considered significant for a particular function (e.g., sediment retention), but due to the current land use of adjacent areas, it now receives substantial sediment input and thereby performs the sediment-trapping function at a significant level.

W-PAWF also does not consider the condition of the adjacent upland (e.g., level of disturbance) or the actual water quality of the associated waterbody as important metrics for assessing the health of individual wetlands. Determining “wetland health” was not part of this study. Collection and analysis of some of these data were done for another part of this study but were not incorporated into the preliminary functional assessment.

We further emphasize that the preliminary assessment does not obviate the need for more detailed assessments of the various functions. This assessment should be viewed as a starting point for more rigorous assessments, as it attempts to cull out wetlands that may likely provide significant functions based on generally accepted principles and the source information used for this analysis. Further review of the wetland form/function protocols and study findings will undoubtedly lead to refinements of the study results in the future. The preliminary assessment done for this study is most useful for regional or watershed planning purposes. For site-specific evaluations, additional work will be required, especially field verification and collection of site-specific data for potential functions (e.g., following the HGM assessment approach as described by Brinson 1993a and other onsite evaluation procedures). This is particularly true for assessments of fish and wildlife habitats and biodiversity. Other sources of data may exist to help refine some of the findings of this report. Additional modeling could be done, for example, to identify habitats of likely significance to individual species of animals (based on their specific life history requirements).

Wetland Restoration Site Inventory

The results of this inventory were derived from air photointerpretation with review of hydric soils data and updated wetland and land use/cover geospatial data. Time did not permit for field checking, so results should be conservative. Areas identified as potential Type 1 restoration sites had visible evidence of restoration potential (e.g., wet depressions in cropland and fill sites without buildings). Rather than piecemeal restoration of small isolated wetlands, wetland restoration of large wetland blocks (e.g., restoring huge flatwood interfluves) appears more beneficial to a goal of restoring wetland ecosystems. To accomplish this, hydric soil information should be consulted. These data will reveal significantly larger areas of hydric soils, presumably former wetlands that are now cultivated, where smaller presently isolated farmed wetlands, small impoundments, and/or vegetated wetlands could be linked together to form a larger vegetated wetland that can be connected to an existing wetland. Where hydric soil data are not available in digital form, this could be done by visual examination of soil survey maps or perhaps by simply drawing lines around the ditch network to predict the extent of former wetlands. This type of evaluation can be made by consulting the wetland restoration site maps which can be used as references for identification large-scale restoration projects. Field work, however, is required to evaluate the true restoration potential of any site as there are often limitations and other issues (e.g., landowner support) that can only be determined during field inspection.

Appropriate Use of this Report

The report provides a basic characterization of wetlands in the two subject watersheds including a preliminary assessment of wetland functions in these areas. Keeping in mind the limitations mentioned above, the results are a first-cut or initial screening of each watershed's wetlands to designate wetlands that may have a significant potential to perform different functions. The targeted wetlands have been identified as being predicted to perform a given function at a significant level presumably important to the watershed's ability to provide that function. "Significance" is a relative term and is used in this analysis to identify wetlands that are likely to perform a given function at a level above that of wetlands not designated.

While the results are useful for gaining an overall perspective of the watershed's wetlands and their relative importance in performing certain functions, the report does not identify differences among wetlands of similar type and function. The latter information is often critical for making decisions about wetland acquisition and designating certain wetlands as more important for preservation versus others with the same categorization. Additional information may be gained through consulting with agencies having specific expertise in a subject area and by conducting field investigations to verify the preliminary assessments. When it comes to actually acquiring wetlands for preservation, other factors must be considered. Such factors may include: 1) the condition of the surrounding area, 2) the ownership of the surrounding area and the wetland itself, 3) site-specific assessment of wetland characteristics and functions, 4) more detailed comparison with similar wetlands based on field data, and 5) advice from other agencies (federal, state, and local) with special expertise on priority resources (e.g., for wildlife habitat, contact appropriate federal and state biologists). The latter agencies may have site-specific information or field-based assessment methods that can aid in further narrowing the choices to help insure that the best wetlands are acquired for the desired purpose.

The report is a watershed-based wetland characterization for two watersheds. The report does not make any comparisons between these watersheds. Be advised that there may be characteristics (e.g., water quality and habitat concerns) that actually make acquisition or preservation of certain wetlands in one of these watersheds or in a particular subbasin, a higher priority than protection of similar wetlands in the other watershed or other subbasins. This was beyond the scope of the present study.

The report is useful for general natural resource planning, as an initial screening for considering prioritization of wetlands (for acquisition, restoration, or strengthened protection), as an educational tool (e.g., helping the public and nonwetland specialists better understand the functions of wetlands and the relationships between wetland characteristics and performance of individual functions), and for characterizing the differences among wetlands in terms of both form and function within each watershed.

Rationale for Preliminary Functional Assessments

The list of functions evaluated included ten functions: 1) surface water detention, 2) streamflow maintenance, 3) nutrient transformation, 4) sediment and other particulate retention, 5) coastal storm surge detention and shoreline stabilization, 6) inland shoreline stabilization, 7) fish and shellfish habitat, 8) waterfowl and waterbird habitat, 9) other wildlife habitat, and 10) conservation of biodiversity. The criteria used for identifying these functions through the digital wetland database are discussed below. The criteria were developed by the principal author of the report based on previous work and reviewed and modified for the subject watersheds based on comments from U.S. Fish and Wildlife Service field personnel and specialists from the Maryland Department of Natural Resources (see Acknowledgments).

In developing a protocol for designating wetlands of potential significance, wetland size was generally disregarded from the criteria, with few exceptions (i.e., surface water detention, other wildlife habitat, and biodiversity functions). This approach was followed because it was felt that the State and others using the digital database and charged with setting priorities should make the decision on appropriate size criteria as a means of limiting the number of priority wetlands, if necessary. Our study was intended to present a more expansive characterization of wetlands and their likely functions and not to develop a rapid assessment method for ranking wetlands for acquisition, protection, or other purposes.

Surface Water Detention

This function is important for reducing downstream flooding and lowering flood heights, both of which aid in lessening property damage from such events. In a landmark report on the relationships between wetlands and flooding at the watershed scale, Novitzki (1979) reported that watersheds with 40 percent coverage by lakes and wetlands had significantly reduced flood flows -- lowered by as much as 80 percent -- compared to similar watersheds with no or few lakes and wetlands in Wisconsin. Floodplain wetlands, other lotic wetlands (basin and flat types), estuarine fringe wetlands along coastal rivers, and estuarine island wetlands in these rivers provide this function at significant levels. Wetlands dominated by trees and/or dense stands of shrubs (with higher frictional resistance) could be deemed to provide a higher level of this function as such vegetation may further aid in flood desynchronization versus similar wetlands with emergent cover. Trees and dense shrubs produce high roughness which helps dissipate energy and lower velocity of flood waters. This relationship (woody vegetation vs. emergents) was not applied to the data set as emergent wetlands along waterways are also likely to provide significant flood storage. Floodplain width could also be an important factor in evaluating the significance of performance of this function by individual wetlands (e.g., for acquisition or strengthened protection). There is no quantitative information to establish a significance threshold for size so floodplain width was not used as a selection factor in this study.

While lotic floodplain and basin wetlands were identified as having possible high potential for surface water detention, lotic wetlands higher on the landscape (i.e., lotic flat wetlands) are not inundated as often as these types and were therefore designated as having some potential. Although all ponds may be locally important as surface water storage basins, only the throughflow ponds were identified as having high potential for surface water detention due to their location on the landscape.

For terrene wetlands, size was considered to be an important factor for determining relative significance for storing surface water. The larger the area, the more water storage capacity, all other things being equal. Terrene wetlands 50 acres and greater in size (excluding any on barrier islands) were designated as having moderate to high potential for surface water detention. These areas represent broad flats with an undulating microtopography where precipitation falling on the land surface accumulates. Many of these wetlands are sources of streams. Moreover, many also have ditches running into them from adjacent agricultural lands which further increases the likelihood of significant surface water detention. Smaller terrene wetlands (20-50 acres in size) that were not ditched were considered to have some potential for this function. Since they are not ditched, they should retain precipitation and surface water runoff from local areas.

Streamflow Maintenance

Many wetlands are sources of groundwater discharge and some may be in a position to sustain streamflow in the watershed. Such wetlands are critically important for supporting aquatic life in streams. Terrene headwater wetlands (by definition, the sources of streams) perform these functions at notable levels. Lotic wetlands along first order streams may also be important for streamflow maintenance; they were also designated as headwater wetlands. Groundwater discharging into streamside wetlands may contribute substantial quantities of water for sustaining baseflows. Floodplain wetlands are known to store water in the form of bank storage, later releasing this water to maintain baseflows. This also aids in reducing flood peaks and improving water quality (Whiting 1998). Among several key factors affecting bank storage are porosity and permeability of the bank material, the width of the floodplain, and the hydraulic gradient (steepness of the water table). The wider the floodplain, the more bank storage given the same soils. Gravel floodplains drain in days, sandy floodplains in a few weeks to a few years, silty floodplains in years, and clayey floodplains in decades. In good water years, wide sandy floodplains may help maintain baseflows.

For this preliminary analysis, floodplain wetlands on nonsandy soils were designated as important for streamflow maintenance due to the above relationship. Narrow floodplains in the Coastal Bays watershed were classified as having as moderate to high potential for this function. They may actually be better represented as having some potential for this function. Review of this document by local experts should help clarify this. Headwater wetlands associated with streams were also identified in the moderate to high potential category for this function. Wetlands in headwater positions that were connected to streams via a drainage ditch network were viewed as having some potential for streamflow maintenance as such structures facilitate water flow to streams downslope.

Nutrient Transformation

All wetlands recycle nutrients, but those having a fluctuating water table are best able to recycle nitrogen and other nutrients. Vegetation slows the flow of water which causes deposition of mineral and organic particles and nutrients (nitrogen and phosphorus) bound to them, whereas hydric soils are the places where chemical transformations occur (Carter 1996). Microbial action in the soil is the driving force behind chemical transformations in wetlands. Microbes need a food source -- organic matter -- to survive, so wetlands with high amounts of organic matter should have an abundance of microflora to perform the nutrient transformation function. Wetlands are so effective at filtering and transforming nutrients that artificial wetlands are constructed for water quality renovation (Hammer 1992). Natural wetlands performing this function help improve local water quality of streams and other watercourses.

Numerous studies have demonstrated the importance of wetlands in denitrification. Simmons et al. (1992) found high removal of nitrate (greater than 80% removal) from groundwater during both the growing season and dormant season in Rhode Island streamside (lotic) wetlands. Groundwater temperatures throughout the dormant season were between 6.5 and 8.0 degrees C, so microbial activity was not limited by temperature. Even the nearby upland, especially transitional areas with somewhat poorly drained soils, experienced an increase in nitrogen removal during the dormant season. This was attributed to a seasonal rise in the water table that exposed the upper portion of the groundwater to more organic matter (nearer the ground surface), thereby supporting microbial activity and denitrification. Riparian forests dominated by wetlands have a greater proportion of groundwater (with nitrate) moving within the biologically active zone of the soil that makes nitrate susceptible to uptake by plants and microbes (Nelson et al. 1995). Riparian forests on well-drained soils are much less effective at removing nitrate. In a Rhode Island study, Nelson et al. (1995) found that November had the highest nitrate removal rate due to the highest water tables in the poorly drained soils, while June experienced the lowest removal rate when the deepest water table levels occurred. Similar results can be expected to occur in Maryland. For bottomland hardwood wetlands, DeLaune et al. (1996) reported decreases in nitrate from 59-82 percent after 40 days of flooding wetland soil cores taken from the Cache River floodplain in Arkansas. Moreover, they surmised that denitrification in these soils appeared to be carbon-limited: increased denitrification took place in soils with greater amounts of organic matter in the surface layer.

Nitrogen fixation is accomplished in wetlands by microbial-driven reduction processes that convert nitrate to nitrogen gas. Nitrogen removal rates for freshwater wetlands are very high (averaging from 20-80 grams/square meter) (Bowden 1987). The following information comes from a review paper on this topic by Buresh et al. (1980). Nitrogen fixation has been attributed to blue-green algae in the photic zone at the soil-water interface and to heterotrophic bacteria associated with plant roots. In working with rice, Matsuguchi (1979) believed that the significance of heterotrophic fixation in the soil layer beyond the roots has been underrated and presented data showing that such zones were the most important sites for nitrogen fixation in a Japanese rice field. This conclusion was further supported by Wada et al. (1978). Higher fixation rates have been found in the rhizosphere of wetland plants than in dryland plants.

Phosphorus removal is largely done by plant uptake (Patrick, undated manuscript). Wetlands that accumulate peat have a great capacity for phosphorus removal. Wetland drainage can, therefore, change a wetland from a phosphorus sink to a phosphorus source. This is a significant cause of water quality degradation in many areas of the world including the United States, where wetlands are drained for agricultural production. Hydric soils with significant clay constituents fix phosphorus due to its interaction with clay and inorganic colloids. Reduced soils have more sorption sites than oxidized soils (Patrick and Khalid 1974), while the latter soils have stronger bonding energy and adsorb phosphorus more tightly.

From the water quality standpoint, wetlands associated with watercourses are probably the most noteworthy. Numerous studies have found that forested wetlands along rivers and streams ("riparian forested wetlands") are important for nutrient retention and sedimentation during floods (Whigham et al. 1988; Yarbro et al. 1984; Simpson et al. 1983; Peterjohn and Correll 1982). This function by forested riparian wetlands is especially important in agricultural areas. Brinson (1993b) suggests that riparian wetlands along low order streams may be more important for nutrient retention than those along higher order streams.

For this analysis, all lotic wetlands were considered to be performing this function at high or moderate to high levels. Those having soils rich in organic matter should have the highest potential for nutrient transformation. The organic matter in the upper part of the soil (A-horizon) provides for increased microbial populations responsible for denitrification and nutrient transformation as noted above. Lotic wetlands on the following soils were considered to have high potential for nutrient transformation: Chicone, Elkton, Kentuck, Pone, Puckum, Sunken, Muck, Indiantown, Pocomoke, Portsmouth, Rutlege, St. Johns (mucky loamy sand), Mannington, and Nanticoke. These soils have high organic matter content at or near the soil surface. Also, any remaining lotic wetlands designated as floodplains or having a seasonally flooded or wetter water regime, and estuarine vegetated fringe and island wetlands were designated as wetlands with predicted high potential for nutrient transformation. The soils of these wetlands should have substantial amounts of organic matter that would promote microbial activity.

Lotic flat wetlands and terrene outflow wetlands surrounded by cropland (50% or more of their upland perimeter is in contact with cropland) were deemed to have some potential for nutrient transformation. Since farming often introduces agrochemicals and sediment into streams, wetlands between cropland and streams lie in landscape positions to provide a ready means of recycling nutrients.

Retention of Sediments and Other Particulates

Many wetlands owe their existence to being located in areas of sediment deposition. This is especially true for floodplain wetlands. This function supports water quality maintenance by capturing sediments with bonded nutrients or heavy metals (as in and downstream of urban areas). Floodplain wetlands plus lotic fringe and basin wetlands (including lotic ponds) are likely to trap and retain sediments and particulates at significant levels. Estuarine fringe and island wetlands (including nonvegetated types) also accumulate sediments and particulates at notable levels. Salt and brackish marshes in these landforms were predicted to have high potential for significant sediment and particulate retention. Lotic flat wetlands are flooded only for brief periods and less frequently than the wetlands listed above due to their elevation. They were classified as having some potential along with terrene outflow wetlands surrounded by cropland that may now perform this function at a significant level due to erosion of soils induced by cultivation. Isolated ponds may be locally significant in retaining such materials, and were designated as having possible local potential.

Coastal Storm Surge Detention and Shoreline Stabilization

Vegetated wetlands along tidal shores (e.g., bays and coastal rivers) provide these functions. Vegetation stabilizes the soil, thereby preventing erosion. Salt marshes and other vegetated coastal wetlands serve as buffers to reduce erosion of uplands from tidal waters. These wetlands also serve to temporarily store water during storm events. Consequently, the analysis identified all estuarine intertidal vegetated wetlands and seasonally flooded tidal palustrine vegetated wetlands as wetlands of high potential significance regarding these functions. Nontidal palustrine wetlands bordering these wetlands were considered to be of moderate to high significance for this function as they appear in the proper position to temporarily hold coastal surge flood waters. Estuarine intertidal nonvegetated wetlands were identified as having some potential for these functions since they serve as potential water storage areas during low tide stages.

Inland Shoreline Stabilization

Like their coastal (estuarine) counterparts, inland vegetated wetlands located along shorelines of rivers, streams, and lakes help prevent upland erosion and stabilize shorelines. For this analysis, all lotic wetlands (except in-stream ponds and island wetlands) were predicted as having high potential. Estuarine river fringe wetlands also provide shoreline protection, but since they were identified as significant under the coastal storm surge detention/shoreline stabilization function, they were not highlighted here.

Provision of Fish and Shellfish Habitat

The assessment of potential habitat for fish and shellfish is based on general relationships that could be refined for individual species of interest at a later date. For this preliminary assessment, fish and shellfish were first separated into two general categories: estuarine fish and shellfish and freshwater species. All fishes and most aquatic invertebrates require permanent water, yet many also need seasonally flooded and semipermanently flooded wetlands and tidal wetlands for breeding and nursery grounds.

For coastal species, estuarine submerged aquatic beds, unconsolidated shores (tidal flats), and emergent wetlands were designated as having high potential due to their well-known functions as feeding areas and nursery grounds for estuarine fishes and as shellfish habitat. Palustrine tidal emergent wetlands may be important for some estuarine species, but were deemed more significant for freshwater species and were highlighted for the latter rather than for the former.

For freshwater species in general, the assessment emphasized palustrine and riverine tidal emergent wetlands and unconsolidated shores (tidal flats), and, for nontidal regions, semipermanently flooded wetlands over seasonally flooded types due to the longer duration of surface water and palustrine aquatic beds[2]. Palustrine forested wetlands along streams (lotic stream wetlands) were deemed important for maintaining fish habitat as their canopies help moderate water temperatures. Ponds and the shallow marsh-open water zone of impoundments were identified as wetlands having some potential for fish habitat.

Other wetlands providing significant fish habitat may exist, but were not be identified due to the study methods. Such wetlands may be individually identified based on actual observations or culled out from site-specific fisheries information that may be available from the State. Also recall that this assessment is focused on wetlands, not deepwater habitats[3], hence the exclusion of the latter from this analysis. In addition, all wetlands that are significant for the streamflow maintenance function could be considered vital to sustaining the watershed's ability to provide in-stream fish habitat. While these wetlands may not be providing significant fish habitat themselves, they typically support base flows essential to keeping water in streams for aquatic life.

[2]No palustrine aquatic beds were mapped, but these areas could be important fish habitat.

[3]These habitats are the primary residences for fish.

Provision of Waterfowl and Waterbird Habitat

Wetlands considered to be important waterfowl and waterbird habitat were estuarine and riverine emergent wetlands, estuarine mixed emergent/scrub-shrub wetlands, unconsolidated shores (estuarine and riverine tidal flats), palustrine and riverine tidal emergent wetlands, semipermanently flooded wetlands, mixed open water-emergent wetlands (palustrine and lacustrine), and aquatic beds[4] (including estuarine types). Ponds were considered to have some potential for providing waterfowl and waterbird habitat. Seasonally flooded lotic wetlands that were forested or mixtures of trees and shrubs were deemed as wetlands with significant potential for use by wood ducks. Also included as significant habitat for wood ducks were tidal freshwater tidal deciduous forested wetlands (seasonally flooded-tidal and semipermanently flooded-tidal) juxtaposed to estuarine wetlands. This grouping included mixtures of deciduous forested wetlands with scrub-shrub wetlands and emergent wetlands. Some of these forested wetlands may be also be utilized as rookery areas for wading birds.

Estuarine scrub-shrub wetlands, estuarine forested wetlands and palustrine forested wetlands bordering salt marshes in the Coastal Bays watershed were not highlighted in this report. Wading birds may nest in such areas, but rather than pull out the entire swath along the salt marsh edge, we decided to refer users to local biologists for information on such rookeries (contact the Maryland Department of Natural Resources). The significance of such areas should, however, be recognized by users of this report.

Seasonally flooded emergent wetlands were not designated as potentially significant for waterfowl and waterbirds. Field checking of these types may reveal that some are freshwater marshes that should be significant, so screening of these types may reveal additional wetlands of significance.

Provision of Other Wildlife Habitat

The provision of other wildlife habitat by wetlands was evaluated in general terms. Species-specific habitat requirements were not considered. In developing an evaluation method for wildlife habitat in the glaciated Northeast, Golet (1972) designated several types as outstanding wildlife wetlands including: 1) wetlands with rare, restricted, endemic, or relict flora and/or fauna, 2) wetlands with unusually high visual quality and infrequent occurrence, 3) wetlands with flora and fauna at the limits of their range, 4) wetlands with several seral stages of hydrarch succession, and 5) wetlands used by great numbers of migratory waterfowl, shorebirds, marsh birds, and wading birds. Golet subscribed to the principle that in general, as wetland size increases so does wildlife value, so wetland size was an important factor for determining wildlife habitat potential in his approach. Other important variables included dominant wetland class, site type (bottomland v. upland; associated with waterbody v. isolated), surrounding habitat type (e.g., natural vegetation v. developed land), degree of interspersion (water v. vegetation), wetland juxtaposition (proximity to other wetlands), and water chemistry.

---

[4]Note that although no palustrine aquatic beds were mapped, they may be considered significant habitats for waterfowl and waterbirds.

For this project, wetlands important to waterfowl and waterbirds were identified in a separate assessment (see above). Emphasis for assessing "other wildlife" was placed on conditions that would likely provide significant habitat for other vertebrate wildlife (mainly herps, forest interior birds, and mammals). Opportunistic species that are highly adaptable to fragmented landscapes were not among the target organisms, since there seems to be more than ample habitat for these species now and in the future. Rather, animals whose populations may decline as wetland habitats become fragmented by development are of more concern. For example, breeding success of neotropical migrant birds in fragmented forests of Illinois was extremely low due to high predation rates and brood parasitism by brown-headed cowbirds (Robinson 1990). Newmark (1991) reported local extinctions of forest interior birds in Tanzania due to fragmentation of tropical forests. Fragmentation of wetlands is an important issue for wildlife managers to address. Some useful references on fragmentation relative to forest birds are Askins et al. (1987), Robbins et al. (1989), Freemark and Merriam (1986), and Freemark and Collins (1992). The work of Robbins et al. (1989) is particularly relevant to the study watersheds as they addressed area requirements of forest birds in the Mid-Atlantic states. They found that species such as the black-throated blue warbler, cerulean warbler, Canada warbler, and black-and-white warbler required very large tracts of forest for breeding. Table 2 lists some area-sensitive birds for the region. Ground-nesters, such as veery, black-and-white warbler, worm-eating warbler, ovenbird, waterthrushes, and Kentucky warbler, are particularly sensitive to predation which may be increased in fragmented landscapes. Robbins et al. (1989) suggest a minimum size of 7,410 acres to retain all species of the forest-breeding avifauna in the Mid-Atlantic region.

The analysis identified three wetland types as potentially significant for other wildlife: 1) large wetlands ($\geq$ 20 acres) regardless of vegetative cover, 2) smaller diverse wetlands (10-20 acres with multiple cover types), and 3) wetlands along stream corridors that connect large wetland complexes. While the latter were identified only for the Coastal Bays watershed, readers should realize that such corridors are equally important for the Nanticoke watershed. We simply did not have time to delineation such corridors for the Nanticoke.

Given the general nature of this assessment of "other wildlife habitat", the State may want to refine this assessment in the future by having biologists designate "target species" that may be used to identify important wildlife habitats in each watershed. After doing this, they could identify criteria that may be used to identify potentially significant habitat for these species in the watershed. Dr. Hank Short (U.S. Fish and Wildlife Service, retired) compiled a matrix listing 332 species of wildlife and their likely occurrence in wetlands of various types in New England (Appendix C) from ECOSEARCH models (Short et al. 1996, 1999) that he developed with Dr. Dick DeGraaf (U.S. Forest Service) and Dr. Jay Hestbeck (U.S. Fish and Wildlife Service). DeGraaf and Rudis (1986) summarized habitat, natural history, and distribution of New England wildlife. Much of what is in the ECOSEARCH models comes from this source. Freemark and Collins (1992) prepared a list of area-sensitive or forest interior birds of the eastern United States (Appendix D). Information on fish and wildlife use of Maryland’s wetlands from Tiner and Burke (1995) is presented in Appendix E. These sources may be useful starting points for determining relationships between wildlife and wetlands in the Mid-Atlantic region.

Table 2. List of some area-sensitive birds for forests of the Mid-Atlantic region. (Source: Robbins et al. 1989)

Species	Area (acres) at which probability of occurrence is reduced by 50%
Neotropical Migrants	
Acadian flycatcher	37
Blue-gray gnatcatcher	37
Veery	49
Northern parula	1,280
Black-throated blue warbler	2,500
Cerulean warbler	1,700
Black-and-white warbler	543
Worm-eating warbler	370
Ovenbird	15
Northern waterthrush	494
Louisiana waterthrush	865
Canada warbler	988
Summer tanager	99
Scarlet tanager	30
Short-distance Migrants	
Red-shouldered hawk	556
Permanent Residents	
Hairy woodpecker	17
Pileated woodpecker	408

Conservation of Biodiversity

In the context of this report, the term "biodiversity" is used to identify certain wetland types that appear to be scarce or relatively uncommon in the watershed or state, or individual wetlands that possess several different covertypes (i.e., diverse wetland complexes), or complexes of large wetlands. Schroeder (1996) noted that to conserve regional biodiversity, maintenance of large-area habitats for forest interior birds is essential. As noted in the other wildlife habitat discusssion above, Robbins et al. (1989) suggest a minimum forest size of 7,410 acres to retain all species of the forest-breeding avifauna in the Mid-Atlantic region.

For recognizing the conservation of biodiversity function, we attempted to highlight areas that may contribute to the preservation of an assemblage of wetlands that encompass the natural diversity of wetlands in the two study watersheds. Forested areas 7410 acres and larger that contained contiguous palustrine forested wetlands and upland forests were designated as important for maintaining regional biodiversity of avifauna based on recommendations by Robbins et al. (1989). We also identified other large wetlands in the watersheds (e.g., possibly important for interior nesting birds and wide-ranging wildlife in general) and wetlands that were either uncommon types (based on mapping classification, not on Natural Heritage Program data) or complexes of multiple-cover types (not related to timber harvest). All riverine tidal wetlands and oligohaline wetlands were identified as significant for this function because they are often colonized by a diverse assemblage of plants and are among the most diverse plant communities in the Mid-Atlantic region. Estuarine bay and barrier island fringe wetlands of the Coastal Bays watershed were also designated as significant since they represent the only wetlands of these types in the state -- wetlands associated with euhaline embayments and barrier islands. Moreover, relatively undeveloped barrier islands are significant natural resources regionally. The estuarine bay fringe category included tidal freshwater wetlands adjacent to these marshes. Estuarine aquatic beds in these coastal embayments were likewise considered significant.

There was no attempt to incorporate Natural Heritage Program data into this analysis. It is expected that Natural Heritage information will be utilized at a later date by the State for more detailed planning and evaluation. Consequently, the wetlands designated as potentially significant for biodiversity are simply a foundation to build upon. Local knowledge of significant wetlands will further refine the list of wetlands important for this function. For information on rare and endangered species, contact the Maryland Natural Heritage Program. Appendix F contains a listing of endangered and threatened plants compiled from 1990 data (Tiner and Burke 1995), while tables in Appendix E include information on various animals of state concern.

Results

Nanticoke Watershed

Wetland Characterization

Wetlands were classified according to the U.S. Fish and Wildlife Service's official wetland classification system (Cowardin et al. 1979) and by landscape position, landform, and water flow path descriptors following Tiner (2000). Summaries for the study area are given in Tables 3 and 4 and findings are illustrated in Maps 1NW through 4NW. Table 3 summarizes covertypes through the subclass level of the FWS classification ("NWI types"), while Table 4 tabulates statistical data on wetlands by landscape position and landform ("HGM types").

Thirty-one percent of the watershed area (which includes the river itself) is occupied by wetlands. If the river and its tributaries are excluded from the watershed area, the percent of "land" represented by wetlands amounts to 34 percent.

Wetlands by NWI Types

According to the NWI, the Nanticoke watershed had 64,139 acres of wetlands (Table 3). Palustrine wetlands were the most abundant types with nearly 47,000 acres, accounting for 73 percent of the watershed's wetland acreage. Estuarine wetlands totaled almost 16,840 acres and represented 26 percent of the wetlands. Riverine tidal wetlands comprised only 0.5 percent. Forested wetlands were the most abundant type of freshwater wetland, with nontidal types prevailing.

Estuarine wetlands were dominated by emergent wetlands (salt/brackish and oligohaline marshes) which comprised over 90 percent of these wetlands, with the more saline wetlands predominating. Almost 40 percent of the estuarine wetlands were oligohaline (slightly brackish) types. Nearly 250 acres of estuarine forested wetlands were inventoried. These wetlands signify areas where salt marshes are advancing landward into former low-lying forests, due to sea level rise and coastal plain subsidence.

Nontidal wetlands were the predominant palustrine wetland type, accounting for 86 percent of the palustrine wetlands. Tidal fresh wetlands represented only 14 percent (6713.9 acres). Forested wetlands comprised the bulk or 80 percent of the palustrine wetlands, totaling more than 37,500 acres (including mixed types, e.g., forested/scrub-shrub). Twelve percent of the palustrine wetlands were scrub-shrub types, with 5 percent being scrub-shrub and emergent wetlands. The latter category included recently harvested forested wetlands that are now in a state of succession.

Map 1NW shows the general distribution of wetlands in the Nanticoke River watershed according to NWI types. See Appendix A for general descriptions of wetland plant communities for the Coastal Plain.

Table 3. Wetlands in the Nanticoke watershed classified by NWI type to the class level (Cowardin et al. 1979). Other modifiers have been deleted from NWI types for this compilation.

NWI Wetland Type	Acreage	
Estuarine Wetlands		
Emergent (Irregularly flooded)	15,243.4	(oligohaline=6020.4)
Emergent (Regularly flooded)	639.8	(oligohaline=239.0)
Forested	173.9	
Forested/Emergent	67.2	
Scrub-Shrub	78.3	(oligohaline=29.0)
Shrub/Emergent	61.0	(oligohaline=56.3)
Unconsolidated Shore	574.0	(oligohaline=274.4)
Subtotal	**16,837.6**	
Palustrine Wetlands		
Emergent (Nontidal)	302.8	
Emergent (Tidal)	204.4	
Farmed	213.6	
Evergreen Scrub-Shrub/Emergent (Nontidal)	1271.4	
Deciduous Scrub-Shrub/Emergent (Nontidal)	1009.5	
Broad-leaved Deciduous Forested (Nontidal)	13,269.4	
Broad-leaved Deciduous Forested (Tidal)	6060.6	
Needle-leaved Evergreen Forested	3668.8	(including 95.3 tidal)
Mixed Forested (Nontidal)	12,658.4	
Mixed Forested (Tidal)	140.7	(including 26.0 w/cypress)
Deciduous Forested/Emergent	98.7	(including 22.6 tidal)
Evergreen Forested/Scrub-Shrub (Nontidal)	421.4	
Deciduous Forested/Scrub-Shrub	1227.4	(including 95.7 tidal)
Dead Forested (Nontidal)	16.7	
Deciduous Scrub-Shrub	693.3	(including 38.6 tidal)
Needle-leaved Evergreen Scrub-Shrub	3130.1	(including 24.8 tidal)
Mixed Scrub-Shrub	2016.4	(including 31.2 tidal)
Deciduous Scrub-Shrub/Unconsolidated Bottom	5.2	
Unconsolidated Bottom (Nontidal)	548.0	
Subtotal	**46,959.8**	
Riverine Wetlands		
Emergent (Tidal)	298.5	
Unconsolidated Shore (Tidal)	46.4	
Subtotal	**344.9**	
GRAND TOTAL (ALL WETLANDS)	**64,139.2**	

Hydrogeomorphic-Type Wetlands[1]

Nearly 1380 wetlands were inventoried in the Nanticoke River watershed and classified by their hydrogeomorphic features (Table 4). Roughly two-thirds of the individual wetlands (excluding ponds) occurred in terrene landscape positions. These wetlands accounted for 52 percent of the watershed's wetland acreage. Estuarine wetlands had the next highest acreage and comprised 34 percent of the total acreage. Lotic wetlands were third-ranked in extent, making up 13 percent.

From the landform standpoint, interfluve wetlands and fringe wetlands were represented in nearly equal amounts, with the former having a slight edge. With nearly 24,000 acres, interfluve wetlands comprised 37 percent of the wetland acreage, while fringe wetlands associated with the estuary portion of the watershed and tidal fresh waters accounted for 35 percent. Flat wetlands, most of which were likely remnants of once-larger interfluve types, ranked next in abundance, totaling over 11,000 acres and comprising 17 percent of the watershed's wetland acreage. If flat wetlands are combined with interfluve wetlands, their grand total exceeds 50 percent which is not surprising for this Coastal Plain watershed. Less than 1000 acres of basin wetlands were present in the watershed.

Outflow wetlands were the predominant water flow path type. They totaled over 30,000 acres and represented nearly half of the wetland acreage. Bidirectional flow types were second-ranked, accounting for 38 percent, with throughflow wetlands next at 9 percent. Only 3 percent of the wetland acreage was isolated.

Maps 2NW, 3NW, and 4NW show the distribution of wetlands classified according to landscape position, landform, and a combination of landscape position and landform, respectively.

[1] All wetlands, except ponds, were characterized by HGM-type descriptors.

Table 4. Estuarine and freshwater wetlands (excluding 548.0 acres of ponds) in the Nanticoke watershed classified by landscape position, landform, and water flow path (Tiner 2000). See Appendix B for definitions.

Landscape Position	Landform	Water Flow	# of Wetlands	Acreage
Estuarine			**139**	**22,065.6**
	Fringe*	Bidirectional	137	21,817.1
	Island	Bidirectional	2	248.5
Terrene			**937**	**33,400.1**
	Interfluve	Outflow	126	23,720.7
	Basin	Isolated	46	157.9
		Outflow	38	549.3
	Flat	Isolated	347	1813.4
		Outflow	380	7158.8
Lotic River			**96**	**2132.4**
	Floodplain	Bidirectional**	38	1598.5
		Throughflow	1	18.3
	Fringe	Bidirectional**	57	515.6
Lotic Stream			**203**	**5983.4**
	Basin	Throughflow	17	197.1
	Flat	Throughflow	100	2037.9
	(includes 1-2.8 acre flat along the intermittent gradient)			
	Floodplain	Throughflow	86	3748.4
Lentic			**3**	**9.5**
	Basin	Throughflow	3	9.5

*Includes tidal freshwater wetlands along edge of estuary
**Freshwater tidal reach

Maps

A series of 18 maps have been produced at 1:110,000 to profile the Nanticoke's wetlands and watershed. These maps have been distributed to the Maryland Department of Natural Resources. They are included in the CD version and on-line version of this report (see the NWI homepage: wetlands.fws.gov, listed under "reports and publications").

A list of the 18 maps follows:

Map 1NW - Wetlands and Deepwater Habitats Classified by NWI Types
Map 2NW - Wetlands Classified by Landscape Position
Map 3NW - Wetlands Classified by Landform
Map 4NW - Wetlands Classified by Landscape Position and Landform
Map 5NW - Potential Wetlands of Significance for Surface Water Detention
Map 6NW - Potential Wetlands of Significance for Streamflow Maintenance
Map 7NW - Potential Wetlands of Significance for Nutrient Transformation
Map 8NW - Potential Wetlands of Significance for Sediment and Other Particulate Retention
Map 9NW - Potential Wetlands of Significance for Coastal Storm Surge Detention and Shoreline Stabilization
Map 10NW - Potential Wetlands of Significance for Inland Shoreline Stabilization
Map 11NW - Potential Wetlands of Significance for Fish and Shellfish Habitat
Map 12NW - Potential Wetlands of Significance for Waterfowl and Waterbird Habitat
Map 13NW - Potential Wetlands of Significance for Other Wildlife Habitat
Map 14NW - Potential Wetlands of Significance for Biodiversity
Map 15NW - Potential Wetland Restoration Sites
Map 16NW - Condition of Wetland and Waterbody Buffers
Map 17NW - Extent of Natural Habitat in the Watershed
Map 18NW - Extent of Ditches and Condition of Streams

The first four maps depict wetlands by the FWS system (NWI types) and by landscape position/landform (HGM types). Maps 5-14 highlight wetlands that perform each of the assessed functions at a significant level. Maps 15-18 address the other important features of the watershed - potential wetland restoration sites, condition of wetland and stream buffers, the overall extent of natural habitat in the watershed, and the extent of ditching and condition of streams.

Summary of Thematic Map Data

The rationale for preliminary assessment of wetlands for performing each of ten functions is given in an earlier section of this report. The following section summarizes the results for each function. The findings are presented mostly in tabular form within the text.

Surface Water Detention

Roughly 92 percent of the watershed's wetland acreage were categorized as having possible significant potential for this function. Forty-four percent were rated as highly significant, 43 percent as moderate to high, and 5 percent as locally significant (see below).

Predicted with High Potential

Wetland Type	Acreage
Estuarine Fringe (ESFR)	21,817.1
Estuarine Island (ESIS)	245.7
Lentic Basin Throughflow (LEBATH)	8.4
Lotic River Floodplain (LR1FP)	18.3
Lotic River Tidal Floodplain (LR5FP)	1598.5
Lotic River Tidal Fringe (LR5FR)	469.2
Lotic Stream Basin (LS1BA)	197.1
Lotic Stream Floodplain (LS1FP)	3748.4
Throughflow Pond	82.0
--	-------------
Total	28, 184.7

Predicted with Moderate to High Potential

Terrene Basin Outflow (TEBAOU)	400.8
Terrene Flat Isolated (TEFLIS)	512.1
Terrene Flat Outflow (TEFLOU)	3597.6
Terrene Interfluve-basin (TEIFba)	100.9
Terrene Interfluve-flat (TEIFfl)	22,876.7
---	----------
Total	27,488.1

Predicted with Some Potential

Lotic Stream Flat (mostly LS1FL)	2038.0
Terrene Basin Isolated (TEBAIS)	49.1
Terrene Basin Outflow (TEBAOU)	44.9
Terrene Flat Isolated (TEFLIS)	358.7
Terrene Flat Outflow (TEFLOU)	530.9
Terrene Interfluve-flat (TEIFfl)	149.9
--	--------
Total	3171.5

Streamflow Maintenance

About 58 percent of the watershed's wetland acreage were identified as headwater wetlands being potentially significant for streamflow maintenance. Seventeen percent were ranked as highly significant, whereas 41 percent were designated as having some potential.

Predicted With High Potential

Wetland Type	Acreage
Lotic River Floodplain (LR1FP)	18.3
Lotic River Tidal Floodplain (LR5FP)	1534.0
Lotic Stream Basin (LS1BA)	140.8
Lotic Stream Flat (LS1FL)	936.5
Lotic Stream Floodplain (LS1FP)	3748.4
Throughflow Pond	29.8
Outflow Pond	54.4
Terrene Basin Outflow (TEBAOU)	23.1
Terrene Flat Outflow (TEFLOU)	836.1
Terrene Interfluve (TEIF)	3614.2
Total	10,935.6

Predicted with Some Potential (ditched headwater wetlands)

Lotic Stream Basin (LS1BA)	48.4
Lotic Stream Flat (mostly LS1FL)	1098.2
Terrene Basin Outflow ditched (TEBAOU)	285.3
Terrene Flat Outflow (TEFLOU)	5214.8
Terrene Interfluve Outflow (TEIFOU)	19,490.2
Total	26,136.9

Nutrient Transformation

Several wetland types were considered to be potentially important for nutrient cycling. About 46 percent of the watershed's wetlands were identified as potentially significant for this function, with 43 percent predicted to have high potential and 3 percent to have some potential.

Predicted with High Potential

Wetland Type	Acreage
Estuarine Fringe-vegetated (ESFR)	20,978.1
Estuarine Island-vegetated (ESIS)	245.7
Lotic River Floodplain (LR1FP)	18.3
Lotic River Tidal Floodplain (LR5FP)	1576.2
Lotic River Tidal Fringe-vegetated (LR5FR)	162.7
Lotic Stream Basin (LS1BA)	193.3
Lotic Stream Flat (LS1FL)	354.0
Lotic Stream Floodplain (LS1FP)	3748.4
Total	27,276.7

Predicted with Some Potential

Other Lotic* (mostly LS1FL)	117.4
Terrene Basin Outflow* (TEBAOU)	3.6
Terrene Flat Outflow* (TEFLOU)	461.7
Terrene Interfluve Isolated (TEIFIS)	81.8
Terrene Interfluve Outflow (TEIFOU)	1377.4
Total	2041.9

*Effectively surrounded by cropland (>50% of border).

Retention of Sediments and Other Particulates

About 52 percent of the watershed's wetland acreage was designated as having possible significance for sediment and other particulate retention. Forty-four percent were rated as having high potential, with 8 percent predicted to have some potential. Roughly 300 acres of isolated ponds were identified as having possible local significance.

Predicted with High Potential

Wetland Type	Acreage
Estuarine Fringe (ESFR)	21,817.1
Estuarine Island (ESIS)	248.5
Lentic Basin (LEBA)	8.4
Lotic River Floodplain (LR1FP)	18.3
Lotic River Tidal Floodplain (LR5FP)	1598.5
Lotic River Tidal Fringe (LR5FR)	469.2
Lotic Stream Basin (LS1BA)	197.1
Lotic Stream Floodplain (LS1FP)	3747.8
Throughflow Pond	82.0
Total	28,186.9

Predicted with Some Potential

Lotic Stream Flat (mostly LS1FL)	1982.8
Lotic Stream Floodplain (LS1FP)	0.6
Terrene Basin Outflow (TEBAOU)	62.6
Terrene Flat Outflow (TEFLOU)	1104.9
Terrene Interfluve (TEIF)	1748.2
Total	4899.1

Predicted with Local Significance

Isolated Pond	292.6
Total	292.6

Coastal Storm Surge Detention and Shoreline Stabilization

About 42 percent of the watershed's wetland acreage was categorized as possibly having significant potential for coastal surge protection and shoreline stabilization. Wetlands with high potential accounted for 37 percent of the watershed's wetlands. Those designated as having moderate to high potential represented 4 percent, while those predicted as having some potential comprised about 1 percent of the watershed's wetlands.

Predicted with High Potential

Wetland Type	Acreage
Estuarine Fringe-vegetated (ESFR)	21,259.9
Estuarine Island-vegetated (ESIS)	248.5
Lotic River Tidal Fringe (LR5FR)	469.2
Lotic River Tidal Floodplain (LR5FP)	1592.7
Lotic Stream Floodplain (LS1FP)	16.2
Total	23,586.5

Predicted with Moderate to High Potential

Lotic River Tidal Floodplain (LR5FP)	5.9
Lotic Stream Basin (LS1BA)	17.3
Lotic Stream Flat (LS1FL)	60.6
Lotic Stream Floodplain (LS1FP)	960.2
Terrene Basin Outflow (TEBAOU)	54.5
Terrene Flat Outflow (TEFLOU)	747.4
Terrene Interfluve (TEIF)	762.1
Total	2608.0

Predicted with Some Potential Significance

Estuarine Fringe-nonvegetated (ESFR)	557.3
Lotic River Tidal Fringe-nonvegetated (LR5FR)	46.4
Total	603.7

Inland Shoreline Stabilization

Vegetated wetlands along lakes, rivers, and streams help stabilize the soils and protect adjacent uplands from water-borne erosion. Only 12 percent of the watershed's wetland acreage was designated potentially significant for inland shoreline stabilization. The percentage would have been higher if the estuarine river fringe wetlands were included. Since they were already identified as highly significant for the Coastal Storm Surge Detention and Shoreline Stabilization function, they were not included as significant for "inland shoreline" stabilization. They are, however, obviously significant for shoreline stabilization along the estuarine portion of the watershed.

Predicted with High Potential

Wetland Type	Acreage
Lotic River Floodplain (LR1FP)	18.3
Lotic River Tidal Floodplain (LR5FP)	1598.5
Lotic River Tidal Fringe (LR5FR)	170.7
Lotic Stream Basin (LS1BA)	197.1
Lotic Stream Flat (LS1FL)	2038.0
Lotic Stream Floodplain (LS1FP)	3748.4
Total	7771.0

Fish and Shellfish Habitat

Wetlands predicted as significant fish and shellfish habitat represented about 37 percent of the watershed's wetland acreage. Those with high potential significance for estuarine fish and shellfish amounted to 26 percent, whereas 0.6 percent was designated as having high potential for freshwater species. Forested and scrub-shrub wetlands along streams that may be important for moderating stream temperatures comprised 9 percent of the watershed's wetlands. Ponds accounted for less than 1 percent of the watershed's wetlands. Some wetlands not identified as significant for this function may be considered vital to sustaining the watershed's ability to provide in-stream fish habitat, especially those important for streamflow maintenance (see pertinent map).

Predicted with High Potential for Estuarine Species

Wetland Type	Acreage
Estuarine Emergent	15,893.3
Estuarine Unconsolidated Shore (tidal flat)	574.0
Total	16,467.3

Predicted with High Potential for Freshwater Species

Riverine Tidal Unconsolidated Shore	46.4
Riverine Tidal Emergent	298.5
Palustrine Tidal Emergent	32.5
Palustrine Emergent Semipermanently Flooded	10.0
Palustrine Emergent/Unconsolidated Bottom	6.6
Total	394.0

Predicted to Be Important for Maintaining Stream Fish Habitat

Palustrine Forested	5750.3
Palustrine Mixed Forested (with Scrub-Shrub or Emergent Wetland)	26.0
Total	5776.3

Predicted with Some Potential for Freshwater Species

Pond	548.0
Total	548.0

Waterfowl and Waterbird Habitat

About 40 percent of the watershed's wetlands was designated as having potential significance for waterfowl and waterbirds. Twenty-six percent was predicted to have high significance for waterfowl and waterbirds, while another 13 percent was identified as potentially important for wood duck. Ponds were identified as having some potential; they represented less than 1 percent of the watershed's wetlands.

Predicted with High Potential

Wetland Type	Acreage
Estuarine Emergent	15,883.4
Estuarine Unconsolidated Shore (tidal flat)	574.0
Riverine Tidal Emergent	298.5
Palustrine Semipermanently Flooded	22.9
Riverine Tidal Unconsolidated Bottom	46.4
Total	16,825.2

Predicted with Some Potential

Palustrine Unconsolidated Bottom (pond)	548.0
Total	548.0

Predicted with Significance to Wood Duck

Palustrine Tidal Forested	5962.0
Palustrine Nontidal Forested	2146.4
Palustrine Tidal Scrub-Shrub	69.9
Palustrine Nontidal Scrub-Shrub	59.4
Total	8237.7

Other Wildlife Habitat

Most (92%) of the watershed's wetlands were predicted as important to other wildlife. Two categories of wetlands were chosen: 1) wetlands $\geq$ 20 acres and 2) small diverse wetlands (10-20 acres and with 2 or more different covertypes at the class level).

Wetland Type	Acreage
Large Wetlands	58,848.9
Small Diverse Wetlands	137.1
Total	58,986.0

Conservation of Biodiversity

Certain wetland types appeared relatively uncommon in the watershed. While they may be abundant elsewhere in the state, they may be viewed as important for maintaining biodiversity within the limits of the Nanticoke watershed, given the watershed focus of this analysis. The following types were highlighted: 1) oligohaline estuarine scrub-shrub wetlands (85.3 acres), 2) estuarine evergreen scrub-shrub wetlands (53.9 acres), 3) estuarine forested wetlands (173.9 acres), 4) estuarine mixed forested/emergent wetlands (67.2 acres), 5) tidal forested wetlands where bald cypress was co-dominant (26.0 acres), 6) palustrine tidal emergent wetlands (204.4 acres), 7) palustrine tidal scrub-shrub wetlands (94.6 acres), 8) riverine tidal emergent wetlands (298.5 acres), 9) riverine tidal unconsolidated shore wetlands (46.4 acres), 10) palustrine tidal evergreen forested wetlands (95.3 acres), 11) palustrine tidal forested/emergent wetlands (22.6 acres), 12) seasonally flooded and semipermanently flooded emergent wetlands (47.8 acres), 13) seasonally flooded deciduous scrub-shrub wetlands (21.4 acres), and 14) seasonally flooded forested/emergent wetlands (4.1 acres).

Despite their relative abundance in this watershed, estuarine oligohaline emergent wetlands (slightly brackish marshes; 6259.4 acres) were highlighted as significant for biodiversity because they are among the most diverse wetland plant communities in the state. They accounted for 10 percent of the watershed's wetland acreage.

Following recommendations by Robbins et al. (1989) for protecting habitat to maintain the Mid-Atlantic region's forest-breeding avifauna, we located one large interconnected forested tract of 12,839 acres in the southeastern part of the watershed (roughly between Barren Creek and Manumsco Creek). This area contained 10,275 acres of mostly forested wetlands which represent 16 percent of the watershed's wetlands. Besides this significant area, several large wetland complexes were considered to be potentially important for biodiversity. They totaled 16,357 acres and represented about 26 percent of the watershed's wetlands.

Overall, slightly more than 50 percent of the Nanticoke wetlands were designated as potentially significant for biodiversity. Remember that this assessment was based on remote sensing techniques and that known sites important to maintaining biodiversity such as those on record with the Maryland Natural Heritage Program or reported in other sources may not be included since those records were not consulted. Consequently, the listing is conservative and represents a starting point, not an end point for an assessment of wetlands important for conservation of species. These sources could be added to the list at a later date by the State in their future planning and evaluation efforts. Consult the state's MERLIN database for information on "wetlands of special state concern."

Potential Wetland Restoration Sites

Due to the history of human activities in this watershed, there is a wealth of opportunities for wetland restoration. Former wetlands (Type 1 wetland restoration sites) and existing wetlands whose functions may be impaired by ditching, impoundment, excavation, and restricted tidal flows (Type 2 restoration sites) represent these opportunities.

A total of 273 Type 1 wetland restoration sites were identified in the Nanticoke watershed. Sixty-seven percent of the Type 1 acreage was represented by farmed wetlands, while the remainder was comprised of former vegetated wetlands that are now deepwater habitats due to impoundment. The Type 1 total is conservative as many areas of hydric soils (i.e., effectively drained and cultivated in the watershed) were not identified as candidates for wetland restoration. They were not designated because they have undergone major land-leveling and appeared to be productive cropland, virtually indistinguishable from other cropland (i.e., on nonhydric soils) on the aerial photographs. Moreover, it may be difficult to convince landowners to support wetland restoration for such areas. When considering wetland restoration of Type 1 sites, however, it should be possible to pursue restoration of much larger wetlands than the Type 1 data would suggest, since the Type 1 sites are usually surrounded by effectively drained hydric soils.

Type 1 Sites	No. of Sites	Acreage
Effectively drained former wetlands (farmed wetlands)	269	241.8
Impoundments (former vegetated wetlands)	4	118.1
Total	273	359.9

Roughly one-third of the watershed's wetlands were designated as Type 2 sites (degraded wetlands whose functions may be improved by various types of restoration). Most of the Type 2 sites were partly drained wetlands that have been ditched to varying degrees. The effect of drainage on these wetlands must be evaluated in the field on a case-by-case basis. Many of these wetlands may have minimal effects, while many others may be seriously impacted by the drainage ditches. Partly drained wetlands with drier water regimes (e.g., temporarily flooded or seasonally flooded [PFO1Ad and PFO1Cd, for example]) contiguous to wetter wetlands (e.g., seasonally flooded/saturated - PFO1E) may indicate more significant drainage impacts. Some of the impounded wetlands listed under Type 2 sites may include both former vegetated wetlands and uplands (e.g., created wetlands). Field investigations are required to sort out the differences. Nonetheless, most appeared in landscape positions (i.e., adjacent to floodplains) were they could be configured to provide floodplain wetland functions, if desirable. Nearly 150 acres of wetlands where tidal flow may be restricted were identified.

Type 2 Sites	Acreage
Tidally restricted Wetlands	147.3
Impounded Wetlands and Ponds (formerly vegetated wetlands)	211.7
Ditched Palustrine Wetlands	21,771.6
Excavated Wetlands	15.0
------------------------------------	------------
Total	22,145.6

Wetland and Waterbody Buffer Analysis

The condition of the 100m upland buffer zone around wetlands and waterbodies (including ditches) was evaluated. Activities in this zone may affect the quality of wetlands and waterbodies. The upland buffer zone for the Nanticoke watershed amounted to 69,792 acres. Approximately 34 percent of this buffer (or 23,544 acres) still possessed natural vegetation in tact, while 59 percent was in agricultural usage and only 7 percent was developed. Map #16NW shows the condition of this buffer for the watershed.

Natural Habitat Integrity Indices

The values for the nine indices for the Nanticoke watershed are calculated and presented below.

Natural Cover Index = 98,544 acres of natural vegetation/188,410 acres of land in watershed = **0.52**

Stream Corridor Integrity Index (100m buffer = 200m corridor)* = 13,581 acres of natural vegetation in upland buffer/20,552 acres of upland buffer = **0.66**

*Excludes open water areas from assessment; also the index value for the 100m corridor is 0.73, so the narrower buffer zone is in slightly better condition than the 200m corridor

Wetland and Other Waterbody Buffer Index (100m)* = 23181 acres of natural vegetation in upland buffer/46,978 acres of upland buffer = **0.49**

*Excludes stream buffers which are covered under Stream Corridor Integrity Index

Wetland Extent Index* = 25,387 acres of wetlands/31,761 acres of hydric soil map units = **0.79**

*Estimated from hydric soil data available for Dorchester County portion of watershed

Standing Waterbody Extent Index = **1.0** due to impoundment and pond construction

Dammed Stream Flowage Index = 6.5 miles dammed/259.3 miles of perennial nontidal rivers and streams = **0.03**

Channelized Stream Length Index = 101.3 miles of channelized streams/259.3 miles of perennial nontidal rivers and streams = **0.39**

Wetland Disturbance Index = 22,767 acres of altered wetlands/64,139 acres of wetlands = **0.35**

Index of Remotely-sensed Natural Habitat Integrity = $I_{RNHI\ 100}$ = (0.6 x I_{NC}) + (0.1 x I_{SCI200}) + (0.1 x I_{WWB100}) + (0.1 x I_{WE}), + (0.1 x I_{SWE}) - (0.1 x I_{DSF}) - (0.1 x I_{CSL}) - (0.1 x I_{WD}) = (0.6 x 0.52) + (0.1 x 0.66) + (0.1 x 0.49) + (0.1 x 0.79) + (0.1 x 1.0) - (0.1 x 0.03) - (0.1 x 0.39) - (0.1 x 0.35) = **0.53**

The above indices provide evidence of a stressed system. A pristine watershed has an index value of 1.0 for natural habitat integrity. The value of 0.53 for the Nanticoke watershed signifies significant human modification. While stream corridors seem to be in reasonable shape re: natural vegetation (66% of the 200m corridor and 73% of the 100m corridor are in natural vegetation), about half of the wetland and other waterbody buffer has been developed. Overall, the Nanticoke watershed has lost about half of its natural habitat and almost 40 percent of its streams have been channelized. While slightly more than half (52%) of the land in the watershed is covered with “natural vegetation”, about 42 percent is in agriculture and only 6 percent is developed. Application of these indices to individual subbasins within the watershed could aid in targeting areas for preservation and restoration.

Extent of Ditching

Approximately 551 miles of ditches were inventoried by this project. This total accounts for 1.9 miles of ditches per square mile of land area. Map #18NW shows the extent of ditching in the Nanticoke watershed.

Coastal Bays Watershed

Wetland Characterization

Wetlands were classified according to the U.S. Fish and Wildlife Service's official wetland classification system (Cowardin et al. 1979) and by landscape position, landform, and water flow path descriptors following Tiner (2000). Summaries for the study area are given in Tables 5 and 6 and findings are illustrated in Maps 1CB through 4CB. Table 5 summarizes covertypes through the subclass level of the FWS classification ("NWI types"), while Table 6 tabulates statistical data on wetlands by landscape position and landform ("HGM types").

Nineteen percent of the watershed area (which includes all the bays) is occupied by wetlands. If the bays are excluded from the watershed total, the percent of “land” represented by wetlands comes to 31 percent.[2]

Wetlands by NWI Types

According to the NWI, the Coastal Bays watershed had nearly 1500 wetlands totaling 36,435 acres. Estuarine and palustrine wetlands were nearly equally abundant, with the former having slightly more acreage (18,153.5 vs. 17,757.0 acres). Estuarine wetlands accounted for 50 percent of the wetlands and palustrine wetlands represented 49 percent. The 525 acres of marine wetlands (intertidal beaches) inventoried made up about 1 percent of the wetland acreage.

Emergent wetlands (salt and brackish marshes) comprised about 91 percent of the estuarine wetlands. Unconsolidated shores (tidal flats) represented 6 percent, while scrub-shrub wetlands accounted for about 3 percent of the estuarine wetlands. Technically classified as deepwater habitat, eelgrass beds totaling 8,311 acres occurred in the shallow bay waters behind Assateague Island.

Forested wetlands were the predominant palustrine type in the watershed accounting for 74 percent of the palustrine wetlands. Scrub-shrub wetlands were next in abundance among these wetlands, representing about 14 percent. Emergent wetlands (including shrub/emergent mixtures) made up 8 percent. The remaining palustrine wetlands were ponds (unconsolidated shores; about 3%) and farmed wetlands (less than 1%).

Map 1CB shows the distribution of wetlands in the Coastal Bays watershed according to NWI types. See Appendix A for general descriptions of wetland plant communities for the Coastal Plain.

[2] Land mass is represented by uplands plus wetlands; deepwater habitats are excluded.

Table 5. Wetlands in the Coastal Bays watershed classified by NWI type to the class level (Cowardin et al. 1979). Other modifiers have been deleted for this compilation.

NWI Wetland Type	Acreage
Marine Wetlands	
Unconsolidated Shore (Beaches)	**524.8**
Estuarine Wetlands	
Emergent (Regularly flooded)	50.7
Emergent (Irregularly flooded)	16,404.9
Emergent/Shrub	44.0
Scrub-Shrub	514.4
Evergreen Forested	39.4
Deciduous Forested/Shrub	15.2
Unconsolidated Shore	1084.9 (w/181.6 irregularly flooded)
Subtotal	**18,153.5**
Palustrine Wetlands	
Emergent (Nontidal)	669.0
Emergent (Tidal)	6.2
Emergent/Scrub-Shrub (Nontidal)	737.3
Emergent/Scrub-Shrub (Tidal)	51.5
Broad-leaved Deciduous Forested (Nontidal)	10,215.6
Broad-leaved Deciduous Forested (Tidal)	179.5
Needle-leaved Evergreen Forested (Nontidal)	165.7
Mixed Forested	1543.0 (includes 2.6 tidal)
Forested/Emergent (Nontidal)	25.9
Evergreen Forested/Scrub-Shrub (Nontidal)	15.5
Deciduous Forested/Deciduous Shrub	852.9 (includes 18.0 tidal)
Deciduous Forested/Evergreen Shrub (Nontidal)	121.7
Deciduous Scrub-Shrub (Nontidal)	404.1
Deciduous Scrub-Shrub (Tidal)	47.4
Needle-leaved Evergreen Scrub-Shrub (Nontidal)	1290.3
Needle-leaved Evergreen Scrub-Shrub (Tidal)	21.8
Mixed Scrub-Shrub (Nontidal)	730.1
Mixed Scrub-Shrub (Tidal)	18.1
Unconsolidated Bottom (Nontidal)	614.2 (includes 3.3 uncon. shore)
Farmed	47.2
Subtotal	**17,757.0**
GRAND TOTAL (ALL WETLANDS)	**36,435.3**

Hydrogeomorphic-Type Wetlands[3]

Slightly more than half of the wetland acreage and 39 percent of the individual wetlands in the Coastal Bays watershed were associated with estuaries. They included typical estuarine wetlands (the salt and brackish tidal wetlands of Cowardin et al. 1979) plus tidally influenced freshwater wetlands along the upland edge of the estuarine reaches of the watershed (e.g., seasonally flooded-tidal palustrine forested wetlands). Terrene wetlands accounted for 36 percent of the wetlands by acreage and nearly half of the wetlands by number (Table 6). This contrast means that, on average, terrene wetlands were much smaller in size than estuarine wetlands. Lotic wetlands ranked third in both abundance (12% of the wetlands by number) and acreage (10% of the wetland acreage).

From the landform perspective, fringe wetlands were most abundant due to the predominance of estuarine wetlands. They accounted for 48 percent of the wetland acreage. Interfluve wetlands were second-ranked, representing 24 percent of the acreage. Flats were next-ranked, comprising just over 10 percent of the acreage. Most of the flats are remnants of interfluve wetlands that have been fragmented by the conversion to cropland. Floodplain wetlands had about 300 acres fewer than the flats and therefore ranked fourth in acreage (nearly 10%). Island wetlands and basin wetlands each represented about 4 percent of the wetland acreage.

Considering water flow path for freshwater wetlands, four types were found in the Coastal Bays watershed: 1) outflow, 2) throughflow, 3) bidirectional flow (associated with lakes, estuaries, and tidal rivers), and 4) isolated. Due to the tidal influence in this watershed, bidirectional flow dominated, affecting over 43 percent of the wetlands by number and about 57 percent by acreage (nearly 21,000 acres). For wetlands beyond the reach of the tide, outflow types (including outflow ponds) predominated with about 12,053 acres (about 20% by number and 33% of the total wetland acreage). Throughflow wetlands (including in-stream ponds) accounted for over 2,400 acres. Isolated wetlands were second-ranked in number (538 including ponds), but occupied only 1,137 acres, showing that most of these wetlands were small (about 2 acres on average). Many were fragments of once larger wetlands.

Maps 2CB, 3CB, and 4CB show the distribution of wetlands in the Coastal Bays watershed as classified by landscape position, landform, and a combination of landscape position and landform, respectively.

[3] Note all wetlands except ponds were categorized by HGM-type descriptors. Ponds were classified according to pond types such as isolated (174 ponds/272.6 acres), outflow (50/105.7), bidirectional (6/42.8), or throughflow (93/189.8).

Table 6. Estuarine and freshwater wetlands (excluding 610.9 acres of ponds) in the Coastal Bays watershed classified by landscape position, landform, and water flow path (Tiner 2000). See Appendix B for definitions.

Landscape Position	**Landform**	**Water Flow**	**# of Wetlands**	**Acreage**
Marine	Fringe	Bidirectional	*	**524.8**
Estuarine			**583**	**18,592.9**
	Fringe*	Bidirectional	344	16,939.8
	Island	Bidirectional	239	1653.1
Terrene			**727**	**13,179.5**
	Interfluve	Outflow	114	8691.4
	Basin	Isolated	183	280.7
		Outflow	65	429.8
	Flat	Isolated	181	583.6
		Outflow	150	2826.2
		Throughflow	34	367.8
Lotic Stream			**184**	**3,523.5**
	Basin	Throughflow	9	16.7
		Bidirectional***	1	2.2
	Flat	Throughflow	11	27.3
	Floodplain	Throughflow	93	1833.9
		Bidirectional***	70	1643.4
Lentic	Basin	Bidirectional	**1**	**3.5**

* Did not compute; ocean beaches.
**Includes tidal freshwater wetlands along edge of estuary.
***Freshwater tidal reach.

Maps

A series of 18 maps have been produced at 1:98,000 to profile the Coastal Bays' wetlands and watershed. These maps have been distributed to the Maryland Department of Natural Resources. They are included in the CD version and on-line version of this report (see the NWI homepage: wetlands.fws.gov listed under "reports and publications").

A list of the 18 maps follows:

Map 1CB - Wetlands and Deepwater Habitats Classified by NWI Types
Map 2CB - Wetlands Classified by Landscape Position
Map 3CB - Wetlands Classified by Landform
Map 4CB - Wetlands Classified by Landscape Position and Landform
Map 5CB - Potential Wetlands of Significance for Surface Water Detention
Map 6CB - Potential Wetlands of Significance for Streamflow Maintenance
Map 7CB - Potential Wetlands of Significance for Nutrient Transformation
Map 8CB - Potential Wetlands of Significance for Sediment and Other Particulate Retention
Map 9CB - Potential Wetlands of Significance for Coastal Storm Surge Detention and Shoreline Stabilization
Map 10CB - Potential Wetlands of Significance for Inland Shoreline Stabilization
Map 11CB - Potential Wetlands of Significance for Fish and Shellfish Habitat
Map 12CB - Potential Wetlands of Significance for Waterfowl and Waterbird Habitat
Map 13CB - Potential Wetlands of Significance for Other Wildlife Habitat
Map 14CB - Potential Wetlands of Significance for Biodiversity
Map 15CB - Potential Wetland Restoration Sites
Map 16CB - Condition of Wetland and Waterbody Buffers
Map 17CB - Extent of Natural Habitat
Map 18CB - Extent of Ditches and Condition of Streams

The first four maps depict wetlands by the FWS system (NWI types) and by landscape position/landform (HGM types). Maps 5-14 highlight wetlands that perform each of the assessed functions at a significant level. Maps 15-18 address the other important features of the watershed - potential wetland restoration sites, condition of wetland and stream buffers, the overall extent of natural habitat in the watershed, and the extent of ditches and condition of streams.

Summary of Thematic Map Data

The rationale for preliminary assessment of wetlands for performing each of ten functions is provided in an earlier section of this report. The following section summarizes the results for each function. The findings are presented mostly in tabular form within the text.

Surface Water Detention

Roughly 35 percent of the Coastal Bays watershed's wetland acreage was categorized as being potentially significant for this function. Ten percent were rated as having high potential, 24 percent with moderate to high potential, and about 1 percent with some potential for surface water detention.

Predicted with High Potential

Wetland Type	Acreage
Lotic Stream Basin (LS1BA)	16.7
Lotic Stream Floodplain (LS1FP)	1832.9
Lotic Tidal Stream Basin (LS5BA)	2.2
Lotic Tidal Stream Floodplain (LS5FP)	1643.4
Instream Pond	184.0
Total	3679.2

Predicted with Moderate to High Potential*

Terrene Interfluve (TEIF)	7665.0
Terrene Basin Outflow (TEBAOU)	9.3
Terrene Flat Outflow (TEFLOU)	993.1
Terrene Flat Throughflow (TEFLTH)	128.7
Total	8796.1

*Part of a wetland 50 acres or larger in size

Predicted with Some Potential

Lotic Stream Flat (LS1FL)	27.3
Terrene Interfluve Outflow* (TEIFOU)	56.3
Terrene Basin Isolated* (TEBAIS)	48.1
Terrene Flat Isolated* (TEFLIS)	87.4
Terrene Basin Outflow* (TEBAOU)	0.5
Terrene Flat Outflow* (TEFLOU)	208.4
Total	428.0

*Part of a 20- to 50-acre wetland and not ditched

Streamflow Maintenance

Nearly 40 percent of the watershed's wetland acreage was identified as potentially significant for streamflow maintenance. Thirty-one percent was rated as having moderate to high potential, while 8 percent was designated as having some potential significance.

Predicted With Moderate to High Potential

Wetland Type	Acreage
Terrene Basin Outflow (TEBAOU)	49.8
Terrene Flat Outflow (TEFLOU)	1051.6
Terrene Interfluve Outflow (TEIFOU)	6565.5
Terrene Flat Throughflow (TEFLTH)	23.5
Lotic Stream Basin (LS1BA)	14.3
Lotic Stream Flat (LS1FL)	9.6
Lotic Floodplain (LS1FP)	1832.9
Lotic Tidal Floodplain (LS5FP)	1643.4
Throughflow Headwater Pond	38.1
Outflow Headwater Pond	80.2
Total	11,308.9

Predicted with Some Potential*

Lotic Stream Basin (LS1BA)	1.1
Outflow Pond	5.6
Terrene Interfluve Outflow (TEIFOU)	2125.8
Terrene Basin Outflow (TEBAOU)	56.9
Terrene Flat Outflow (TEFLOU)	754.0
Terrene Flat Throughflow (TEFLTH)	82.5
Total	3025.9

*Ditched headwater wetlands

Nutrient Transformation

Several wetland types were considered to be potentially important for nutrient cycling. About 67 percent of the watershed's wetlands were identified as potentially significant for this function. Those predicted to have high potential represented about 58 percent of the Coastal Bays watershed's wetlands.

Predicted with High Potential

Wetland Type	Acreage
Estuarine Fringe (ESFR)	16,125.3
Estuarine Island (ESIS)	1382.7
Lotic Stream Basin (LS1BA)	15.4
Lotic Stream Flat (LS1FL)	15.3
Lotic Stream Floodplain (LS1FP)	1833.9
Lotic Stream Tidal Floodplain (LS5FP)	1643.4
Lotic Stream Tidal Basin (LS5BA)	2.2
Total	21,018.2

Predicted with Some Potential*

Terrene Interfluve Outflow (TEIFOU)	2821.7
Terrene Basin Outflow (TEBAOU)	62.9
Terrene Flat Outflow (TEFLOU)	481.3
Total	3365.9

*Effectively surrounded by cropland (>50% of border).

Retention of Sediments and Other Particulates

Nearly 72 percent of the watershed's wetland acreage was predicted to significantly contribute to sediment and other particulate retention. Sixty-one percent of the wetlands were rated as having high potential, while about 10 percent were designated as having some potential.

Predicted with High Potential

Wetland Type	Acreage
Estuarine Fringe (ESFR)	16,939.8
Estuarine Island (ESIS)	1653.1
Lotic Stream Basin (LS1BA)	16.7
Lotic Stream Floodplain (LS1FP)	1833.9
Lotic Stream Tidal Floodplain (LS5FP)	1643.4
Lotic Stream Tidal Basin (LS1BA)	2.2
In-stream Pond	189.8
Total	22,278.9

Predicted with Some Potential

Lotic Flat (LS1FL)	27.3
Terrene Interfluve Outflow (TEIFOU)	2821.7
Terrene Basin Outflow (TEBAOU)	62.9
Terrene Flat Outflow (TEFLOU)	481.3
Terrene Flat Throughflow (TEFLTH)	238.6
Total	3631.8

Predicted with Local Significance

Isolated Pond	268.7
Total	268.7

Coastal Storm Surge Detention and Shoreline Stabilization

About 59 percent of the watershed's wetland acreage was categorized as having possible high potential for coastal surge protection and shoreline stabilization. While most of the acreage of potentially significant wetlands for this function is estuarine wetlands, freshwater tidal wetlands were included since they do serve as significant water storage reservoirs for coastal storm surge. They represented 53 percent of the watershed's wetlands. Wetlands bordering estuarine and tidal fresh wetlands were considered to have moderate to high potential for storm surge floodwater detention due to their low topography and adjacency to tidal waters. They represented 4 percent of the Coastal Bays watershed's wetlands. Nonvegetated tidal wetlands were designated as having some potential. They comprised about 2 percent of the wetlands.

Predicted with High Potential

Wetland Type	Acreage
Estuarine Fringe-vegetated (ESFR)	16,304.2
Estuarine Island-vegetated (ESIS)	1385.4
Lotic Stream Tidal Basin (LS5BA)	2.2
Lotic Stream Tidal Floodplain (LS5FP)	1643.4
Total	19,335.2

Predicted with Moderate to High Potential*

Terrene Basin Outflow (TEBAOU)	309.1
Terrene Flat Outflow (TEFLOU)	1011.7
Terrene Flat Throughflow (TEFLTH)	56.4
Total	1377.2

*Palustrine nontidal wetlands bordering estuarine fringe and lotic tidal wetlands

Predicted with Some Potential

Estuarine Fringe-nonvegetated (ESFR)	635.6
Estuarine Island-nonvegetated (ESIS)	267.7
Total	903.3

Inland Shoreline Stabilization

Vegetated wetlands along lakes, rivers, and streams help stabilize the soils and protect adjacent uplands from water-borne erosion. About 10 percent of the watershed's wetland acreage was represented by wetlands with a high potential to help stabilize inland shorelines.

Predicted with High Potential

Wetland Type	Acreage
Lotic Stream Basin (LS1BA)	16.7
Lotic Stream Flat (LS1FL)	27.3
Lotic Stream Floodplain (LS1FP)	1832.9
Lotic Stream Tidal Floodplain (LS5FR)	1643.4
Lotic Stream Tidal Basin (LS5BA)	2.2
Total	3522.5

Fish and Shellfish Habitat

Wetlands with predicted significant potential to serve as or support fish and shellfish habitat represented about 59 percent of the watershed's wetland acreage. Wetlands with high potential for estuarine species dominated the totals. They alone comprised 48 percent of the watershed's wetlands. High potential habitat for freshwater species was less abundant, making up only 0.1 percent of the Coastal Bays wetlands. Forested and shrub wetlands along streams were deemed potentially significant for maintaining stream water temperatures that are important to resident fishes. They accounted for 9 percent of the watershed's wetland acreage. Although not designated as important for fish habitat, headwater wetlands (e.g., terrene outflow types) are likely to be vital to sustaining the watershed's ability to provide in-stream fish habitat; they can be observed on the map of streamflow maintenance.

Predicted with High Potential for Estuarine Species

Wetland Type	Acreage
Estuarine Aquatic Bed (eelgrass beds)*	8311.4
Estuarine Emergent Wetland	16,462.5
Estuarine Unconsolidated Shore (tidal flats)	1084.9
Total	25,858.8 (includes "deepwater" eelgrass beds)

*Deepwater habitat but important shallow-water, submerged aquatic bed community for fish and shellfish; some beds may be intermittently exposed and may be classified as wetlands.

Predicted with High Potential for Freshwater Species

Palustrine Tidal Emergent	12.0
Palustrine Emergent Semipermanently Flooded	31.7
Total	43.7

Predicted to Be Important for Maintaining Stream Fish Habitat*

Lotic and Palustrine Forested	3024.3
Lotic and Palustrine Mixed Forested/Shrub	130.3
Total	3154.6

*These forested and shrub wetlands are likely important for maintaining water temperatures in streams and thereby vital to maintaining suitable fish habitat.

Predicted With Some Potential for Freshwater Species

Wetland Type	Acreage
Pond	610.9
------------	-------
Total	610.9

Waterfowl and Waterbird Habitat

Wetlands of potential significance for waterfowl and waterbirds represent 53 percent of the watershed's wetlands. The abundance of estuarine wetlands in this watershed led to a high percentage of wetlands being designated with high potential: 48 percent of the wetlands. Over 8300 acres of estuarine aquatic beds (deepwater habitats) were also identified as having high potential for supporting waterfowl and waterbirds. Over 1000 acres of additional wetlands (or 3 percent of the wetland acreage) were predicted to be important for wood duck, while 611 acres of ponds were identified as likely to provide some waterfowl and waterbird habitat.

Predicted with High Potential

Wetland Type	Acreage
Estuarine Aquatic Bed*	8311.4
Estuarine Fringe (salt/brackish emergent)	15,079.8
Estuarine Fringe (salt/brackish shrub/emergent)	37.0
Estuarine Fringe (freshwater emergent)	12.0
Estuarine Fringe (nonvegetated)	814.5
Estuarine Island (emergent)	1382.7
Estuarine Island (nonvegetated)	270.4
Semipermanently Flooded Emergent	33.8
Semipermanently Flooded Forested/Shrub	12.3
Semipermanently Flooded Shrub/Emergent	3.5
Total	25,957.4

*Classified as deepwater habitat

Predicted with Some Potential Significance

Palustrine Unconsolidated Bottom (pond)	610.9
Total	610.9

Predicted with Significance to Wood Duck

Lotic and Palustrine Forested	1097.5
Lotic and Palustrine Forested/Shrub	28.3
Lotic and Palustrine Scrub-Shrub	23.0
Total	1148.8

Other Wildlife Habitat

Three categories of wetlands were identified as potentially significant for other wildlife: 1) wetlands $\geq$ 20 acres, 2) small diverse wetlands (10-20 acres and with 2 or more different covertypes at the class level), and 3) wetland corridors that may be important for wildlife travel. No acreage data were tabulated for the latter category. The “other wildlife habitat” map shows these corridors that interconnect wetlands and may be valuable as travel corridors for terrestrial wildlife in the watershed. The first two wetland types comprised about 84 percent of the watershed's wetland acreage.

Wetland Type	Acreage
Large Wetlands	30,362.5
Small Diverse Wetlands	325.3
Total	30,687.8

Conservation of Biodiversity

Certain wetland types appeared relatively uncommon in the watershed. While some may be abundant elsewhere in the state, they may be viewed as important for maintaining biodiversity within the limits of the Coastal Bays watershed, given the watershed focus of this analysis. The following types were highlighted: 1) interdunal wetlands (325.4 acres), 2) fresh tidal wetlands contiguous to salt marshes (211.4 acres), 3) semipermanently flooded emergent and/or scrub-shrub wetlands (4.6 acres; not ditched or impounded)[4], and 4) seasonally flooded emergent or mixed emergent/shrub wetlands (9.7 acres; not ditched or impounded).

All estuarine aquatic beds (8311.4 acres) and salt marshes (15,469.1 acres) associated with Assateague Island (barrier island marshes) and the saline embayments (Chincoteague Bay and others) were viewed as important for maintaining biodiversity. This region is the only area in the State where these types of saline bays occur.

Robbins et al. (1989) suggested a minimum size of 7,410 acres to retain all species of the forest-breeding avifauna in the Mid-Atlantic region. One such area totaling 9102 acres was found in the Coastal Bays watershed. It is a combination of forested wetlands (2455.4 acres) and forested uplands (6646.4 acres).

Also in reviewing the color-coded watershed map of NWI wetland types, 5 to 6 large wetland complexes (5911.0 acres of wetlands) appeared worth noting due to their possible importance to species conservation.

In total, about two-thirds of the wetlands in the watershed were rated as important for biodiversity. The reason this total is very high is mainly due to the inclusion of most of the watershed's estuarine wetlands in the assessment. Remember that this assessment was based on remote sensing techniques and that known sites important to maintaining biodiversity such as those on record with the Maryland Natural Heritage Program or reported in other sources may not be included since those records were not consulted. Consequently, the listing represents a starting point, not an end point for an assessment of wetlands important for conservation of species. These sources should be reviewed as the next step in future planning and evaluation efforts for the watershed. Consult the state's MERLIN database for information on "wetlands of special state concern."

[4]These wetlands should be field checked to verify that they are not ditched or impounded and evaluated as to their significance for biodiversity.

Potential Wetland Restoration Sites

Due to the history of human activities in this watershed, there is a wealth of opportunities for wetland restoration. Former wetlands (Type 1 wetland restoration sites) and existing wetlands whose functions may be impaired by ditching, impoundment, excavation, and restricted tidal flows (Type 2 restoration sites) represent these opportunities. A total of 25,365 acres were identified in the Coastal Bays watershed as having potential for wetland restoration.

Of the Type 1 sites, farmed wetlands predominated by number (89% of the sites) while representing about 33 percent of the acreage. Tidally restricted areas (former vegetated wetlands that are now open water) had a slightly higher acreage total (119 acres vs. 108 acres for farmed wetlands). Five sites made up this acreage. Twenty-two filled areas were identified as potential Type 1 restoration sites and two impounded areas were believed to constructed in sites that were formerly vegetated wetlands. Restoration of Type 1 sites would produce a net gain in wetland acreage.

Type 1 Sites	No. of Sites	Acreage
Effectively drained former wetlands (now mostly farmed wetlands)	247	108.4
Filled former wetlands	22	62.6
Impounded former vegetated wetlands	2	42.3
Tidally restricted former vegetated wetlands (now open water)	5	118.9
Total	276	332.2

The Type 1 totals could have been larger, but their identification was conservative -- based on recognizable photo-signatures. If all former hydric soil areas were included as Type 1 sites, the total for this category would have been enormous, since about 40 percent of the hydric soil map units are not classified as wetlands. They were not designated because they have undergone major land-leveling and appeared to be productive cropland, virtually indistinguishable from other cropland (i.e., on nonhydric soils) on the aerial photographs. Moreover, it may be difficult to convince landowners to support wetland restoration for such areas. When considering wetland restoration of identified Type 1 sites, however, it should be possible to pursue restoration of much larger wetlands than the Type 1 data would suggest, since the Type 1 sites are usually surrounded by effectively drained hydric soils.

Nearly all the designated wetland restoration acreage in the watershed was comprised of Type 2 sites (mostly wetlands with altered hydrology). In total, they represent nearly 70 percent of the watershed's wetlands. Drained wetlands dominated the Type 2 restoration sites, with nearly equal amounts of palustrine and estuarine wetland acreage affected. Site-specific studies are required to evaluate the scope and effect of the ditching and to determine whether wetland restoration should be considered. Many of these wetlands may have minimal effects, while many others may be seriously impacted by the drainage ditches. Partly drained nontidal wetlands with drier water regimes (e.g., temporarily flooded or seasonally flooded [PFO1Ad and PFO1Cd, for example]) contiguous to wetter wetlands (e.g., seasonally flooded/saturated - PFO1E) may indicate more significant drainage impacts. Type 2 restoration sites also included

63 acres of tidally restricted sites. These sites are mostly ponds that appeared to be former tidal wetlands. Restoration of Type 2 sites would produce net gains in one or more wetland functions.

Type 2 Sites	Acreage
Tidally restricted Wetlands	62.9
Impounded Wetlands and Ponds (formerly vegetated wetlands)	170.6
Ditched Palustrine Wetlands*	12,351.4
Ditched Estuarine Wetlands*	12,446.5
Excavated Wetlands	1.0
Total	25,032.4

*The effect of drainage on wetlands must be evaluated in the field on a case-by-case basis.

Wetland and Waterbody Buffer Analysis

The condition of a 100m upland buffer zone around wetlands and waterbodies (including ditches) was evaluated. The upland buffer zone for the Coastal Bays watershed amounted to 55,421 acres. Approximately 41 percent of this buffer (22,759 acres) still had natural vegetation in tact, while 42 percent was in agricultural usage and 17 percent developed. Map #16CB shows the condition of this buffer for the watershed.

Natural Habitat Integrity Indices

The values for the nine indices for the Coastal Bays watershed are calculated and presented below.

Natural Cover Index = 64,074 acres of natural vegetation/116,560 acres of land in watershed = **0.55**

Stream Corridor Integrity Index (100m buffer = 200m corridor)* = 5183 acres of natural vegetation in upland buffer/9526 acres of upland buffer = **0.54**

*Excludes open water areas from assessment; also the index value for the 100m corridor is 0.59, so the narrower buffer zone is in slightly better condition than the 200m corridor

Wetland and Other Waterbody Buffer Index (100m)* = 20,021 acres of natural vegetation in upland buffer/37,489 acres of upland buffer = **0.53**

*Excludes stream buffers which are covered under Stream Corridor Integrity Index

Wetland Extent Index = 36,435 acres of wetlands/62,156 acres of hydric soil map units = **0.59**

Standing Waterbody Extent Index = **1.0** due to impoundment and pond construction

Dammed Stream Flowage Index = 1.6 miles dammed/169.7 miles of perennial nontidal rivers and streams = **0.01**

Channelized Stream Length Index = 165.2 miles of channelized streams/169.7 miles of perennial nontidal rivers and streams = **0.97**

Wetland Disturbance Index = 25,442.9 acres of altered wetlands/36,435 acres of wetlands = **0.70**

Index of Remotely-sensed Natural Habitat Integrity = $I_{RNHI\ 100}$ = (0.6 x I_{NC}) + (0.1 x I_{SCI100}) + (0.1 x I_{WWB100}) + (0.1 x I_{WE}), + (0.1 x I_{SWE}) - (0.1 x I_{DSF}) - (0.1 x I_{CSL}) - (0.1 x I_{WD}) = (0.6 x 0.55) + (0.1 x 0.54) + (0.1 x 0.53) + (0.1 x 0.59) + (0.1 x 1.0) - (0.1 x 0.01) - (0.1 x 0.97) - (0.1 x 0.70) = **0.42**

The above indices provide evidence of a severely stressed system. A pristine watershed has an index value of 1.0 for natural habitat integrity. The Coastal Bays watershed's natural habitat integrity value was 0.42, indicating much human disturbance. Nearly half of its natural habitats are gone, possibly as much as 40 percent of its wetlands have been converted to other uses, and about half of its wetland and waterbody buffers are now developed (e.g., cropland, residential development, or other land uses). Virtually all of its streams have been channelized. Also while 60 percent of its pre-settlement wetlands may still exist, about 70 percent of them are altered in some way (e.g., ditched, impounded, or excavated). About 32 percent of the watershed is being used for agriculture and another 13 percent is developed. Application of the natural habitat integrity indices to individual subbasins within the Coastal Bays watershed may aid in setting priorities for protection and restoration.

Extent of Ditching

Approximately 448.7 miles of ditches were inventoried by this project. This total accounts for 2.4 miles of ditches per square mile of land area. Map #18CB shows the extent of ditching in the Coastal Bays watershed along with information on the condition of streams (channelized; dammed; or unaltered).

Comments on Fragmentation

One outstanding issue involved fragmentation of wetlands. Although not a prime objective of the current study, we attempted to identify wetlands that were subjected to significant fragmentation. In both watersheds, many small wetlands were actually the remaining fragments (remnants) of once large wetlands. For this report, we attempted to apply the fragmentation descriptor ("fg") to wetlands that were divided into two or more units by roads, railroads, or other structures which likely disrupted the hydrology and created an increased risk for wildlife crossing. Fragmentation in this context, therefore, did not address the issue from the broad landscape perspective which is more encompassing and requires documentation of changes in large tracts of forests as a result of increasing human-use (e.g., conversion to agricultural lands or to other types of human development such as residential housing or urbanization).

During the study, the question arose as to what level of separation constitutes significant fragmentation of wetlands to warrant "flagging"? While a 4-lane highway (interstate) should clearly represent sufficient fragmentation, does a 2-lane paved road produce similar consequences? How about unpaved roads? Perhaps the fragmentation descriptor should be restricted to wetlands that are chopped up into multiple pieces by developments and associated roadways and only note the presence of a "fragmentation feature" (e.g., I-95) for larger wetlands crossed by major highways. The application of the "fg" descriptor was not as consistent as we would have liked as this was only our second attempt using it. Consequently, we have not reported any results on the extent of fragmented wetlands in the watershed, yet these data are in the digital database for possible future use.

Another question arose in applying the fragmentation descriptor to wetland polygons - should this descriptor be applied to: 1) the entire wetland (main wetland body and the fragmented section), or 2) only to the fragmented piece(s)? Many large wetlands only had a small portion that was fragmented and we don't want to exaggerate the effect of fragmentation.

Conclusions

The findings of this report should be considered preliminary. Field checking should be conducted to validate the interpretations. The report should, however, serve as a guide to wetlands in each watershed and to their functions. It is a starting point for resource planning rather than an end point. The characterization serves as one tool to aid in wetland conservation and watershed management. It should be used with other tools based on field observations and site-specific data.

Acknowledgments

This study was funded by the Maryland Department of Natural Resources through a grant from the National Oceanic and Atmospheric Administration (Coastal Zone Management Award No. NA87OZ0236). Bill Jenkins was the project coordinator, serving as the liasion between the State and the principal investigator (R. Tiner).

Photointerpretation for this project was performed by John Swords and Matt Starr. John did the wetland interpretation including potential restoration sites, while Matt interpreted the land use and cover. Wetland classification following Tiner (2000) was performed by Matt Starr and Herb Bergquist, with Matt focusing on the Coastal Bays watershed and Herb on the Nanticoke. They also performed geographic information processing for these watersheds. Ralph Tiner reviewed their work and developed the correlations between wetland characteristics and wetland functions used to produce the preliminary assessment of wetland functions for each watershed. He also analyzed the data and prepared the project report.

We also thank Bill Jenkins and his staff and co-workers for providing information for use in this study, especially Ken Miller, David Bleil, Tirumal Jallepalli, Glenn Therress, and Paul Kazyak. Others contributing to this study included: Gabe DeAlessio (U.S. Fish and Wildlife Service, Hadley, MA), Greg Breese (USFWS, Delaware Bay Estuary Program, Smyrna, DE), Bob Zepp (USFWS, Chesapeake Bay Field Office, Annapolis, MD), Becky Stanley (USFWS, National Wetlands Inventory Center, St. Petersburg, FL), and Michael Whited (USDA Natural Resources Conservation Service, Hadley, MA).

References

Anderson, J.R., E.E. Hardy, J.T. Roach, and R.E. Witmer. 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data. U.S. Geological Survey, Reston, VA. Geol. Survey Prof. Paper 964.

Askins, R.A., M.J. Philbrick, and D.S. Sugeno. 1987. Relationship between the regional abundance of forest and the composition of forest bird communities. Biol. Cons. 39: 129-152.

Bowden, W.B. 1987. The biogeochemistry of nitrogen in freshwater wetlands. Biogeochemistry 4: 313-348.

Brinson, M. M. 1993a. A Hydrogeomorphic Classification for Wetlands. U.S. Army Corps of Engineers, Washington, DC. Wetlands Research Program, Technical Report WRP-DE-4.

Brinson, M.M. 1993b. Changes in the funcitoning of wetlands along environmental gradients. Wetlands 13; 65-74.

Buresh, R.J., M.E. Casselman, and W.H. Patrick. 1980. Nitrogen fixation in flooded soil systems, a review. Advances in Agronomy 33: 149-192.

Carter, V. 1996. Wetland hydrology, water quality, and associated functions. In: J.D. Fretwell, J.S. Williams, and P.J. Redman (compilers). National Water Summary on Wetland Resources. U.S. Geological Survey, Reston, VA. Water-Supply Paper 2425. pp. 35-48.

Castelle, A.J., A.W. Johnson, and C. Conolly. 1994. Wetland and stream buffer size requirements - a review. J. Environ. Qual. 23: 878-882.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service, Washington, DC. FWS/OBS-79/31.

DeGraaf, R.M. and D.D. Rudis. 1986. New England Wildlife: Habitat, Natural History, and Distribution. U.S.D.A. Forest Service, Northeastern Forest Expt. Station, Amherst, MA. Gen. Tech. Rep. NE-108.

DeLaune, R.D., R.R. Boar, C.W. Lindau, and B.A. Kleiss. 1996. Denitrification in bottomland hardwood wetland soils of the Cache River. Wetlands 16: 309-320.

Desbonnet, A.., P. Pogue, V. Lee, and N. Wolff. 1994. Vegetated Buffers in the Coastal Zone. A Summary Review and Bibliography. Rhode Island Sea Grant, University of Rhode Island, Narragansett, RI. Coastal Resources Center Tech. Rep. 2064.

Finlay, C.S. and J. Houlahan. 1996. Anthropogenic correlates of species richness in southeastern Ontario wetlands. Conserv. Biol. 11(4): 1000-1009.

Freemark, K. and B. Collins. 1992. Landscape ecology of breeding birds in temperate forest fragments. In: J.W. Hagan III and D.W. Johnston (editors). Ecology and Conservation of

Neotropical Birds. Smithsonian Institution Press. pp. 443-453.

Freemark, K.E. and H.G. Merriam. 1986. Importance of area and habitat heterogenity to bird assemblages in temperate forest fragments. Biol. Cons. 36: 115-141.

Golet, F.C. 1972. Classification and Evaluation of Freshwater Wetlands as Wildlife Habitat in the Glaciated Northeast. University of Massachusetts, Amherst, MA. Ph. D. dissertation.

Hammer, D.A. 1989. Constructed Wetlands for Waste Water Treatment. Lewis Publishers, Inc., Chelsea, MI.

Hammer, D.A. 1992. Creating Freshwater Wetlands. Lewis Publishers, Inc., Chelsea, MI.

Keller, C.M.E., C.S. Robbins, and J.S. Hatfield. 1993. Avian communities in riparian forests of different widths in Maryland and Delaware. Wetlands 13(2): 137-144.

Kilgo, J.C., R.A. Sargent, B.R. Chapman, and K.V. Miller. 1998. Effects of stand width and adjacent habitat on breeding bird communities in bottomland hardwoods. J. Wildl. Manag. 62(1): 72-83.

Matsuguchi, T. 1979. In: Nitrogen and Rice. International Rice Research Institute, Los Banos, Philippines. Pp. 207-222.

Mitsch, W.J. and J.G. Gosselink. 1993. Wetlands. Van Nostrand Reinhold, New York, NY.

Naiman, R.J., T.J. Beechie, L.E. Benda, D.R. Berg, P.A. Bisson, L.H. MacDonald, M.D. O'Connor, P.L. Olson, and E.A. Steel. 1992. Fundamental elements of ecologically healthy watersheds in the Pacific Northwest Coastal Region. In: R.J. Naiman (editor). Watershed Management: Balancing Sustainability and Environmental Change. Springer-Verlay, New York, NY. pp.127-188.

Nelson, W.M., A.J. Gold, and P.M. Groffman. 1995. Spatial and temporal variation in groundwater nitrate removal in a riparian forest. J. Environ. Qual. 24; 691-699.

Newmark, W.D. 1991. Tropical forest fragmentation and the local extinction of understory birds in the eastern Usambara Mountains, Tanzania. Conservation Biology 5: 67-78.

Novitzki, R.P. 1979. The hydrologic characteristics of Wisconsin wetlands and their influence on floods, streamflow, and sediment. In: P.E. Greeson et al. (editors). Wetland Functions and Values: The State of Our Understanding. Amer. Water Resources Assoc., Minneapolis, MN. pp. 377-388.

Patrick, W.H., Jr. undated. Microbial reactions of nitrogen and phosphorus in wetlands. The Utrecht Plant Ecology News Report No. 11 (10): 52-63.

Patrick, W.H., Jr., and R.A. Khalid. 1974. Phosphate release and sorption by soils and sediments: effect of aerobic and anaerobic conditions. Science 186: 53-55.

Peterjohn, W.T. and D.L. Correll. 1984. Nutrient dynamics in an agricultural watershed: observations on the role of a riparian forest. Ecology 65: 1466-1475.

Robbins, C.S., D.K. Dawson, and B.A. Dowell. 1989. Habitat area requirements of breeding forest birds of the Mid-Atlantic states. Wildlife Monogr. 103: 1-34.

Robinson, S.K. 1990. Effects of Forest Fragmentation on Nesting Songbirds. Illinois Natural History Survey, Champaign, IL.

Schroeder, R.L. 1996. Wildlife Community Habitat Evaluation Using a Modified Species-Area Relationship. U.S. Army Corps of Engineers, Waterways Expt. Station, Vicksburg, MS. Wetlands Research Program Tech. Rep. WRP-DE-12.

Short, H. L., J. B. Hestbeck, and R. W. Tiner. 1996. Ecosearch: a new paradigm for evaluating the utility of wildlife habitat. In: Conservation of Faunal Diversity in Forested Landscapes. R. M. DeGraaf and R. L. Miller (editors). Chapman & Hall, London. pp. 569-594.

Short, H.L., J.B. Hestbeck, and R.M. DeGraaf. 1999 (in press). New England Wildlife: An Adaptive Model for Ecosystem Management, ECOSEARCH. U.S.D.A. Forest Service, Northeastern Forest Experiment Station, Broomall, PA. Gen. Tech. Rep. NE-xxx.

Simmons, R.C., A.J. Gold, and P.M. Groffman. 1992. Nitrate dynamics in riparian forests: groundwater studies. J. Environ. Qual. 21: 659-665.

Simpson, R.L., R.E. Good, R. Walker, and B.R. Frasco. 1983. The role of Delaware River freshwater tidal wetlands in the retention of nutrients and heavy metals. J. Environ. Qual. 12: 41-48.

Tiner, R.W. 1997. NWI Maps: What They Tell Us. National Wetlands Newsletter 19(2): 7-12. (Copy available from USFWS, ES-NWI, 300 Westgate Center Drive, Hadley, MA 01035)

Tiner, R.W. 1998. In Search of Swampland: A Wetland Sourcebook and Field Guide. Rutgers University Press, New Brunswick, NJ.

Tiner, R. W. 2000. Keys to Waterbody Type and Hydrogeomorphic-type Wetland Descriptors for U.S. Waters and Wetlands (Operational Draft). U.S. Fish and Wildlife Service, Northeast Region, Hadley, MA.

Tiner, R.W. and D.G. Burke. 1995. Wetlands of Maryland. Maryland Dept. of Natural Resources, Annapolis, MD and U.S. Fish and Wildlife Service, Hadley, MA. Cooperative National Wetlands Inventory report.

Wada, H., S. Panichsakpatana, M. Kimura, and Y. Takai. 1978. Soil Sci. Plant Nutr. 24: 357-365.

Wang, L., J. Lyons, P. Kanehl, and R.Gatti. 1997. Influences of watershed land use on habitat quality and biotic integrity of Wisconsin streams. Fisheries 22(6): 6-12.

Whigham, D.F., C. Chitterling, and B. Palmer. 1988. Impacts of freshwater wetlands on water quality: a landscape perspective. Environ. Manag. 12: 663-671.

Whiting, P.J. 1998. Bank storage and its influence on streamflow. Stream Notes July 1998. Stream Systems Technology Center, Rocky Mountain Research Station, Fort Collins, CO.

Wissmar, R.C., J.E. Smith, B.A. McIntosh, H.W. Li, G.H. Reeves, and J.R. Sedell. 1994. Ecological Health of River Basins in Forested Regions of Eastern Washington and Oregon. U.S.D.A. Forest Service, Pacific Northwest Research Station, Corvallis, OR. Gen. Tech. Rep. PNW-GTR-326.

Yarbro, L.A., E.J. Kuenzler, P.J. Mulholland, and R.P. Sniffen. 1984. Effects of stream channelization on exports of nitrogen and phosphorus from North Carolina Coastal Plain watersheds. Environ. Manag. 8: 151-160.